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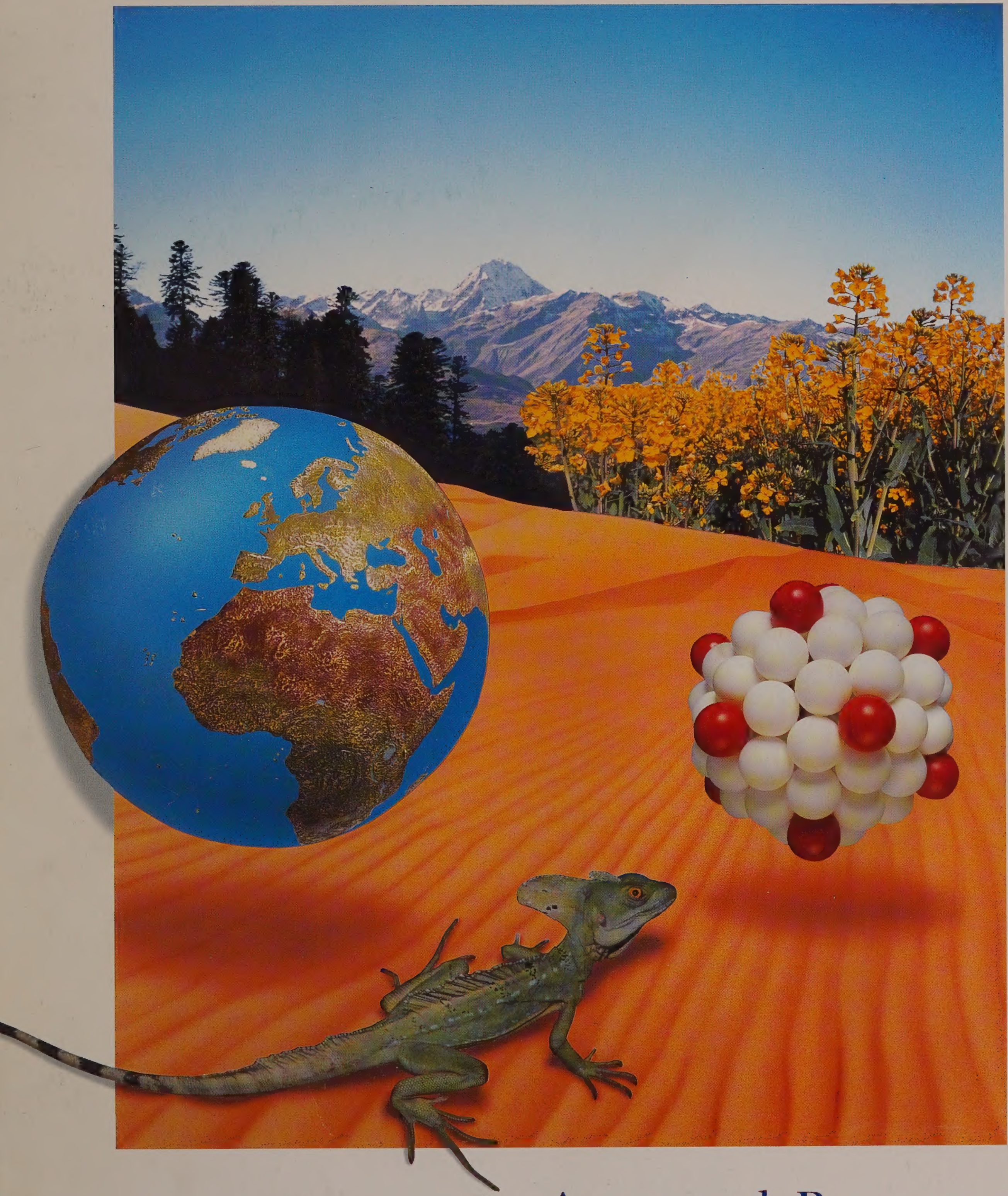

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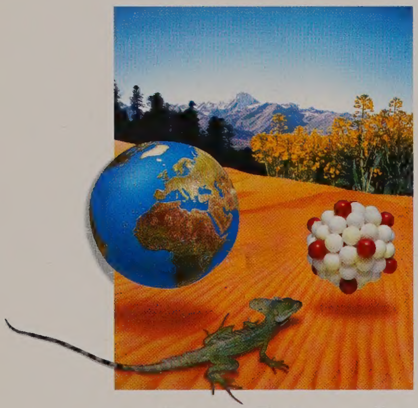

***Front cover:** The deserts may bloom*

Fundamental research by AFRC scientists is helping to unravel the myriad of biological processes essential for life on this planet - from the assembly and nature of virus particles, through the complex whole organism organisation determining growth, development and behaviour in plants and animals, to environmental and ecological issues of global significance - AFRC is at work around the world.

Photography: Sean Ryan, with thanks to Bristol Zoo and Dr. P.G.Meredith University College, London.

THE AGRICULTURAL AND FOOD RESEARCH COUNCIL (AFRC)

AFRC's aims are:

- to provide an internationally competitive research and training base in the non-medical biological sciences and biotechnology, including agricultural and food science.
- to advance fundamental and strategic scientific knowledge in support of national wealth creation, with due regard to environmental protection, animal welfare and the public interest.
- to provide an independent source of scientific knowledge to inform effective policy-making in industrial and environmental matters, food quality and safety, animal welfare and related issues.
- to encourage and foster scientific collaboration within the European Community and beyond.

THE AGRICULTURAL AND FOOD RESEARCH SERVICE

AFRC research in university groups and in its institutes is co-ordinated throughout the Agricultural and Food Research Service with research carried out at the five Scottish Agricultural Research Institutes (SARIs) which are funded by DAFS. This ensures an integrated research capability in England and Wales and Scotland. AFRC provides DAFS with scientific advice on its research programme. DAFS representatives sit on various management bodies of AFRC. In recognition of this special working relationship, this Report contains reference to work at some of the SARIs.

AT WORK AROUND THE WORLD

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AFRC

REPORT OF THE AGRICULTURAL AND FOOD RESEARCH COUNCIL

To the Secretary of State for Education and Science

The Agricultural and Food Research Council, as required by Schedule 1 of the Science and Technology Act, 1965, submits the following report on its activities during the period from 1 April 1989 to 31 March 1990.

Mr M A Grant, Chairman

Dr B G Jamieson, Acting Secretary

Laid before Parliament pursuant to Schedule 1 of the Science and Technology Act, 1965.

20 November 1990.

Published by the Agricultural and Food Research Council, Wiltshire Court, Farnsby Street, Swindon SN1 5AT. (Tel 0793 514242)

From Spring 1991:- Polaris House, North Star Avenue, Swindon SN2 1UH. (Tel 0793 413200)

AT WORK AROUND THE WORLD

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MEMBERS OF COUNCIL AND SENIOR STAFF

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Dyfed Seeds

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University of Birmingham

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NERC

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DTI

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Welsh Office

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DANI

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SERC

Professor H J Newby
ESRC

Dr D A Rees FRS
MRC

Professor H Smith FRS
Royal Society

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Maitland Mackie
Mackie's Aberdeen Dairy Co Ltd

Members

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Director of Animal Health Research

O H Colburn CBE
Crown Estates Commission
(deceased August 1990)

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Director, AFRC Central Office

G T Pryce
Business Consultant
Director, H P Bulmer Holdings plc

B Staples
Head of Buildings and Supplies, AFRC

Professor W D P Stewart FRSE FRS
Acting Chairman and Secretary, AFRC

Professor J L Stoddart
Director of Grassland and Environmental Research

S H Visscher
Chief Finance Officer, AFRC

Adviser

P Powis
Land Services Section
Chief Valuers Office

COUNCIL STRATEGY COMMITTEE

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Members

Professor J L Harper CBE FRS
University of North Wales, Bangor

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Director, AFRC Central Office

Maitland Mackie
Mackie's Aberdeen Dairy Co Ltd

Professor A W Nienow FEng
University of Birmingham

Professor H Smith FRS
Royal Society

Professor R Whittenbury
University of Warwick

AFRC MANAGEMENT BOARD at 31 March 1990

Professor W D P Stewart FRSE FRS (Chairman)
Acting Chairman and Secretary, AFRC

Professor F J Bourne
Director of Animal Health Research

Professor D L Georgala CBE
Director of Food Research

Professor R B Heap FRS
Director of Animal Physiology and Genetics Research

Dr B G Jamieson
Director of AFRC Central Office

Professor T Lewis
Acting Director of Arable Crops Research

Professor J Matthews CBE
Director of Engineering Research

Professor J L Stoddart
Director of Grassland and Environmental Research

Professor T R Swinburne
Director of Horticultural Research

Professor H W Woolhouse
Director of Plant Science Research

E J Weeple
(Assessor, DAFS)

AFRC SENIOR STAFF at 31 March 1990

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Acting Chairman and Secretary, AFRC

J M Y Dickens
Chief Personnel Officer

Dr A V Harrison
Head of Policy, Planning and Assessment Division

Dr B G Jamieson
Director of Central Office

Dr J V Lake
Head of Science Division

S H Visscher
Chief Finance Officer

CHAIRMAN'S INTRODUCTION

I was delighted to accept an invitation from the Secretary of State for Education and Science to become Chairman of the Agricultural and Food Research Council in succession to Lord Selborne and thus to be associated with the Council's work.

I am convinced that agricultural producers and food processors need to be underpinned by a strong science base if they are to respond to the new technical, business and political challenges of the 1990s and next century, both in the developed West and in lesser developed countries.

The AFRC has an excellent reputation for first-class science in support of wealth creation. Its present high standing owes much to the wisdom and qualities of my predecessor, John Selborne who guided the Council through much of the 1980s. It was fitting that he should be awarded the 1990 Massey-Ferguson National Award for Services to UK Agriculture in recognition of his work for agricultural and food R & D.

I greatly look forward to the challenge and excitement of leading the Council through a period of rapid scientific advance and new emerging opportunities for technology transfer and application.

Alistair Grant

THE YEAR IN REVIEW

1989-90 has been successful for AFRC from both scientific and organisational standpoints. Increased funding from the Department of Education and Science is allowing the realisation of important scientific, training and restructuring policies, thus marking a new phase in the Council's development.

During the year there was significant progress towards strengthening the research base across institutes and universities; in developing strategies of research training to provide the skilled and flexible manpower resources needed for the future; in enhancing collaborative links with other research bodies and with industry; and in strengthening research partnerships worldwide.

In noting these achievements, the Council must record its gratitude to the Earl of Selborne who provided inspired leadership and who served for an extended period as Chairman until his retirement in December 1989.

Professor J P Hearn, Deputy Secretary since 1987 and much concerned with promoting scientific excellence throughout the AFRC, resigned in February 1990 to take up a prestigious research post in the United States.

At the very end of the year the Council learned with regret that its Secretary, Professor W D P Stewart FRS, was to leave in October 1990 to become the Government's Chief Scientific Adviser. The Council wishes him every success in his new and demanding role.

SCIENTIFIC INNOVATION AND EXCELLENCE

The theme of this year's Report "AFRC: at work around the World" reflects Council's concern that its research base meets both national and emerging European and global opportunities. Science is competitive and international. AFRC is committed to ensuring that UK science competes effectively with that of other major advanced countries. Increasingly this will be measured through bilateral and multilateral collaborations which enhance the national UK programme.

The Report covers some of the most innovative of the Council's fundamental and strategic research programmes. One example is the elucidation of molecular signalling in cells (page 12). The significance of this research, which has implications for understanding processes as diverse as embryogenesis and the control of manic depression, was recognised in the 1989 Albert Lasker Basic Medical Research Award to Dr M J Berridge FRS of the AFRC Institute of Animal Physiology and Genetics Research. Further evidence of its wide-ranging relevance comes from citation analysis which reveals that a review by Dr Berridge and colleagues was the second most cited paper of the decade. Dr Berridge's prize is only one of many national and international prizes awarded to AFRC scientists during 1989-90.

INDEPENDENT, SCIENCE-BASED KNOWLEDGE

A key goal of AFRC research is to provide independent, science-based knowledge; for example, for the formulation of effective national policies pertinent to the biologically based industries, environmental considerations, food quality and safety, animal welfare and related issues. Two such areas of current interest are highlighted in this Report. The first, consumer attitudes and the relationships between diet and health(page 24), illustrates how AFRC is bringing the scientific rigour of traditional disciplines to new initiatives in the public interest. The second, aspects of environmental protection and conservation of the UK countryside(page 29), illustrates collaborative research both with growers and agrochemical companies. Chemicals will remain essential for efficient agriculture and research is directed at optimising their efficiency and minimising waste. One aspect that receives little media attention is the problem of resistance in insect pests, fungal pathogens and weeds which poses a serious threat to agriculture in many parts of the world. Dr R Sawicki FRS of the AFRC Institute of Arable Crops Research recently received a British Crop Protection Council Award for his outstanding research in this area. Sadly, Dr Sawicki has since died.

Council's research into the disease Bovine Spongiform Encephalopathy(BSE) reported in detail in the last two Annual Reports continued to attract both scientific and media attention throughout the year under review. In 1990, AFRC published a document summarising the scientific evidence relating to BSE and addressing specific issues arising from public debate. Scientists at the AFRC/MRC funded Neuropathogenesis Unit in Edinburgh were the first to show that abnormal fibrils in the brains of BSE-infected cattle are chemically similar to those found in sheep affected by scrapie; and that BSE could be transmitted from cattle to mice. Council's work on the molecular biology of transmissible spongiform encephalopathies is further strengthened by the award of an additional £6.3M under the Science Budget Allocations to Research Councils announced in January 1990.

Professor Howard Newby, Chairman of ESRC; Lord Selborne; Dr Caroline Jackson MEP and Professor William Stewart examine a model of the new Polaris House extension. The new building, which will house the Central Offices of the AFRC and ESRC, is scheduled for occupation in February 1991.

AFRC AND PARLIAMENT

During the period of this Report AFRC presented evidence to Parliamentary Committees on a wide range of issues.

House of Lords European Communities Committee: Sub-Committee D (Agriculture and Food) on Nitrates in Water (May 1989).

House of Lords Select Committee on Science and Agriculture: Sub-Committee II - Greenhouse Effect (June 1989).

House of Lords Select Committee on Science and Technology: Sub-Committee II - Definitions on R&D Spending (July 1989).

House of Commons Agriculture Committee Enquiry into Fish Farming (September 1989).

House of Commons Education, Science and Arts Committee Inquiry into Science Policy and the European Dimension (November 1989).

House of Lords European Communities Committee: Sub-Committee(Energy, Transport and Technology) on the Framework Programme of Community Activities in the Field of Research and Technology Development (1990 - 1994) (December 1989).

House of Lords Select Committee on Science and Technology: Sub-Committee II - Nature Conservancy Council (December 1989).

House of Lords European Communities Committee: Sub-Committee D (Agriculture and Food) on The Future of the Rural Society (March 1990).

A FLEXIBLE, HIGHLY SKILLED WORKFORCE

Demographic changes in the 1990s seem likely to bring a shortage of skilled scientific manpower. AFRC has been at the forefront of developing better and wider training opportunities for research workers in universities and in its own institutes, and is seeking to enhance career development and stability (page 60). The commitment to scientific excellence guides the Council's manpower strategy. The UK will have a successful research base only if it nurtures the most able, innovative and flexible scientists - people who can respond to the rapid pace of developments in science. On a European scale, AFRC is looking to develop bilateral fellowship schemes with partners in Europe, and to enhance scientist mobility and exchange.

The efforts of several people at all levels in the AFRC have been recognised in Honours Lists during the year. It is a pleasure to congratulate Sir Barry Cross CBE FRS, former Director of the AFRC Institute of Animal Physiology and Genetics Research, on his receipt of a Knighthood, Professor John Harper FRS, a member of Council since 1980, on the award of a CBE and Professor John Matthews, who retired as Director of Research of AFRC Institute of Engineering Research, on the award of a CBE.

NATIONAL WEALTH CREATION

Collaboration with industry, particularly in the very early stages of pre-competitive research, is essential to the eventual development of products that can compete in the market place. AFRC welcomes the scientific opportunities arising from collaboration with industrial partners. AFRC currently works with about 200 commercial companies, and external income has increased by 10% on the previous year (page 61). In addition AFRC is playing a prominent role in the Government's LINK scheme which aims to accelerate the commercial exploitation of publicly-funded research.

Horticulture is a special case; AFRC's links with the growers and with the ADAS Experimental Horticultural Stations have been rationalised with the integration of the AFRC Institute of Horticultural Research within a new unified R&D organisation for UK horticulture. AFRC has welcomed this development as a positive way of enhancing technology transfer to UK horticulture while maintaining a strong research base to meet the long-term needs of this important sector.

POSITIONING THE COUNCIL FOR THE YEARS AHEAD

Council has completed and published its plans for restructuring the research institutes onto fewer sites as outlined in successive Corporate Plans. The institute reconstruction programme, started somewhat tentatively in 1983, is being funded by a combination of extra grants from the DES and the receipts of surplus property assets, and is on target for completion in 1993. It is central to Council's policy of establishing and maintaining world class research centres, with first rate research expertise and resources, to enable the UK to compete internationally. The construction of improved facilities at fewer sites, with an overall increase in the proportion of scientists at each site, represents sound long-term investment. The seven research institutes cover research areas of: Plant Science; Animal Science; Food and Consumer Affairs; Animal Health and Welfare; Intensive Agriculture and the Environment; Rural Agriculture and the Environment; and Agricultural Engineering.

Council has continued to expand the programme of increased funding for university and polytechnic research and increased the proportion of the Council's Core Science budget fund going to the universities and polytechnics. The HEIs provide the innovative and flexible training base which is crucial to the UK's future as a major industrial force. AFRC has this year increased the number of its postgraduate training awards and is introducing a new postdoctoral fellowships scheme for particularly innovative scientists.

The changes inherent in these policies, though vital for the future of the AFRC, have placed additional pressures on staff. Although compulsory redundancies have been kept to a minimum, some unfortunately have been inevitable. The Council greatly regrets that this was necessary. The general support and understanding of all AFRC staff during this period of restructuring is appreciated.

Last year's Report referred to the then active debate about Research Council boundaries. AFRC has welcomed the moves subsequently announced; these are designed to ensure closer co-operation among the Research Councils under the reconstituted ABRC. AFRC has steadily increased collaborative activities and will continue to do so. Current initiatives include a joint programme with NERC and ESRC on agriculture and the environment. A new programme on clean technologies is being developed in collaboration with SERC. Collaboration with MRC is developing in a number of areas including transgenesis, encephalopathies and nutrition.

INTERNATIONAL COLLABORATION

AFRC has expanded its network of collaborative research in Europe through bilateral agreements and pan-European programmes. AFRC institutes have competed successfully for support within the CEC Framework Programme for R&D, and revenue to Council from the EC increased by 44% compared with the previous year (page 39). Many current issues in the biologi-

Participants at the 1989 Tetrapartite Meeting of leading research administrators from France, Canada, USA and UK, at Rothamsted.

cal sciences require consideration on European and wider scales.

AFRC continues to enjoy good collaborative links with research in the USA, and is working to extend them and those with Canada, Japan, Australia and New Zealand. The 1989 meeting of research administrators from Canada, France, USA and UK (the so-called Tetrapartite Meeting) took place at the AFRC Institute of Arable Crops Research at Rothamsted. Information exchange across Europe and North America, the implications of global warming for agriculture and food production, and intellectual property rights and technology transfer were among the topics discussed. Recent visits are paving the way to closer collaboration with Australia and New Zealand on the implications of climate change and other global environmental issues.

In the developed world, successful application of research in the agricultural and related sciences has met the demands for increased food production and enhanced the safety, quality and variety of food for the consumer. In developing countries the situation is different and provision of sufficient food remains the primary objective. AFRC is actively involved in fundamental research which could play an important role in increasing food production in the Third World (page 51). Much of this research is supported by international and aid agencies.

CONCLUSION

The success of the AFRC depends on the scientists it supports carrying out high quality science effectively in the international arena. The additional support made available from the Science Budget by the Department of Education and Science has been particularly welcome. The Council much values the support and continued good relations which it has enjoyed with the Department of Education and Science and with the Ministry of Agriculture, Fisheries and Food. When priorities have to be set - as they must be - the innovative scientist must be protected. AFRC possesses such scientists in abundance. Innovation coupled to effective technology transfer in concert with industry is a positive and effective way forward for the Council - and the country. ■

A SUSTAINED RESEARCH BASE FOR THE UK

The Agricultural and Food Research Council (AFRC) provides a strong base of fundamental and strategic research in the biological sciences which will determine future progress in many areas of endeavour - in the agricultural and food industries, consumer issues and conservation, and in veterinary and human medicine.

The following pages give examples of some of the exciting areas of current basic, applied and developmental research - and show how AFRC contributes to two important topical issues - consumer attitudes to food, including investigations into why people choose the food they do, the determinants of food quality, and fundamental studies into the relationships between diet, health and aetiology of disease; and the balance between agriculture and conservation in the countryside, including research to minimise nitrate leaching, optimise the efficiency of agrochemicals, and develop alternative strategies for land use in the UK.

AFRC research is identifying the molecular basis of "second messengers" that convey signals at cell surfaces (e.g. from hormones) to mechanisms inside the cell that carry out the required task. This is helping to explain cell function and dysfunction, growth and development and offers new insights into processes as diverse as embryo development and the effect of lithium in controlling manic depression. A new toxin, identified from research on a respiratory disease of pigs, is also likely to contribute to research on cell signalling. The toxin is the most potent growth factor yet discovered. In plant biology we are elucidating the mechanisms of intracellular transport systems that are crucial to many plant functions.

At the level of the gene itself, we report on the use of "antisense" genes which offer novel ways of investigating gene expression and regulation in transgenic plants; on how genes encoding for human antibodies could lead to more effective therapy against infections and cancers; and on the potential for developing leguminous crops resistant to pest attack by using natural nitrogen-fixing bacteria fitted with bacterial genes encoding for toxins that kill insects. Protein engineering offers the potential for designing enzymes and other proteins for specific industrial purposes, for example to operate at particular pH levels. We report on advances in our understanding of structure/function relationships in papaya proteases, including the first description of the tertiary structure of papaya proteinase omega.

Research at the DAFS-funded Hannah Research Institute shows that the hormone relaxin, previously thought to be confined to the ovary or uterus, is produced in the mammary gland. We also report on AFRC research directed at underpinning our understanding of animal welfare and behaviour, specifically on how sheep recognise and bond to their offspring, an area with obvious implications for neonatal care and fostering of orphaned livestock.

AFRC has continued to attract increased contract income from industry and other sources, currently over £16M pa (see pages 61–63). We are currently working in collaboration with about 200 companies, and are to lead a new £6M Government/industry initiative on industrial use of agricultural crops, and British Technology Group is supporting a major new programme on crop protection at the AFRC Institute of Arable Crops Research.

AFRC is continuing to build upon its increased support for research and research training in higher education institutions (see pages 59–60). As part of our strategy to further research education and career development, we have awarded a larger number of research studentships, and launched a new five-year postdoctoral Fellowship scheme. We have also introduced a grant award scheme for "new investigators" designed to support younger researchers at an early stage in their career.

UNE BASE DE RECHERCHE SOLIDE AU ROYAUME UNI

L'AFRC (Conseil de Recherche agro-alimentaire) fournit une base solide pour la recherche stratégique et fondamentale dans le domaine des sciences biologiques, elle déterminera les progrès futurs de l'industrie agro-alimentaire, des questions de consommation et de conservation et de la médecine vétérinaire et humaine.

Les pages suivantes présentent les exemples de quelques secteurs très intéressants de recherche de base, de recherche appliquée et de recherche de développement, ils montrent la façon dont l'AFRC contribue à deux problèmes importants qui sont, d'une part, le comportement des consommateurs vis-à-vis de la nourriture en effectuant des études sur les motivations des consommateurs lors du choix de la nourriture, sur les éléments déterminant la qualité de la nourriture et sur les relations entre le régime, la santé et l'étiologie des maladies, et d'autre part, l'équilibre entre l'agriculture et la conservation de l'environnement en effectuant des recherches pour minimiser la laxivation par le nitrate, pour maximiser l'efficacité des produits agro-chimiques et pour développer des stratégies nouvelles portant sur l'utilisation de la campagne au Royaume Uni.

Les centres de recherche AFRC s'efforcent d'identifier la base moléculaire des "messagers seconds" qui envoient des signaux de la surface des cellules,(à partir des hormones) aux mécanismes situés à l'intérieur des cellules pour que ceux-ci exécutent une tâche requise. Ceci permet de comprendre le fonctionnement, le non fonctionnement, la croissance et le développement des cellules, et permet d'éclairer les processus aussi variés que le développement de l'embryon et les effets du lithium lors du contrôle de la psychose maniaque dépressive. Lors d'études sur une maladie respiratoire du porc, une nouvelle toxine a été identifiée et elle contribuera à la recherche sur l'échange des signaux cellulaires. Elle représente le facteur de croissance le plus puissant qui ait été découvert à ce jour. En biologie végétale, nous avons élucidé les mécanismes des systèmes de transport intracellulaire, décisifs pour le fonctionnement des plantes.

En ce qui concerne le gène lui même, nous présentons un rapport sur l'utilisation des gènes "anti-sens" qui offrent de nouvelles voies d'accès pour les recherches sur l'expression et la régulation des gènes dans les plantes transgéniques, sur la façon dont le codage des gènes lors de la création d'anticorps humains pourraient entraîner une thérapie plus efficace contre les infections et les cancers, et enfin, sur les possibilités de produire des produits légumineux capables de résister aux attaques des animaux nuisibles grâce à l'utilisation d'une bactérie naturelle renfermant du nitrogène qui tue les insectes, fixé par un codage de gènes bactériologiques. Les manipulations des protéines offrent des possibilités de création d'enzymes et d'autres protéines pour des applications industrielles spécifiques comme, par exemple, l'utilisation à des niveaux pH particuliers. Nous exposons les progrès effectués dans la compréhension des relations structurelles et fonctionnelles des protéases de papaye, ainsi que la première description de la structure de protéinase de papaye oméga.

Les études menées à l'Institut de Recherche Hannah, financé par le DAFS, ont montré que la relaxine d'hormones est produite dans les glandes mammaires et non dans l'ovaire ou dans l'utérus comme l'on croyait. De plus, nous présentons les faits concernant les recherches de l'AFRC qui permettent de comprendre le comportement et la santé des animaux, et particulièrement la façon dont les moutons reconnaissent leur progéniture et y restent attachés, il s'agit là d'un domaine comportant des implications importantes quant aux soins néo-natals et à l'élevage des animaux orphelins.

L'AFRC continue à attirer des fonds qui proviennent de l'industrie ou d'autres sources, à présent, ils totalisent une somme de plus de seize millions de livres sterling (voir pages 61-63). Nous travaillons, désormais, en collaboration avec environ 200 entreprises et nous avons l'intention de mener une nouvelle initiative gouvernement/industrie d'une valeur de 6 millions de livres dans le cadre de l'utilisation industrielle des produits agricoles. De plus, le Groupe de Technologie Britannique soutient avec un apport de fonds considérable un nouveau projet majeur sur la protection des récoltes, qui est mené à l'Institut AFRC de Recherche sur les Produits Agricoles.

L'AFRC continue à apporter un soutien large à la recherche et à la formation dans les institutions éducatives supérieures (voir pages 59-60). Font partie de notre stratégie de soutien un nombre croissant de bourses d'études; un nouveau projet d'association de cinq ans pour les post-docs, et un nouveau système de bourses pour "chercheurs débutants".

EINE ANHALTENDE FORSCHUNGSBASIS FÜR GROSSBRITANNIEN

Der Agricultural and Food Research Council (AFRC) (Rat für Landwirtschafts- und Ernährungsforschung) liefert eine starke Basis fundamentaler und strategischer Forschung in den biologischen Wissenschaften, die den zukünftigen Fortschritt in vielen Bemühungsgebieten bestimmen wird – in der Landwirtschafts- und Ernährungsindustrie, bei Verbraucherfragen und Umweltschutz sowie in der tierischen und menschlichen Medizin.

Die folgenden Seiten zeigen Beispiele einiger dieser aufregenden Gebiete der augenblicklich grundsätzlichen, angewandten und entwickelnden Forschung – und sie zeigen welchen Beitrag der AFRC bei zwei wichtigen aktuellen Themen liefert – Verhalten des Verbrauchers den Nahrungsmitteln gegenüber, einschließlich Untersuchungen warum die Leute die Nahrungsmittel wählen, die sie wählen, die Bestimmung der Nahrungsmittelqualität sowie grundlegende Studien über die Beziehungen zwischen Diät, Gesundheit und Krankheitsursachen sowie die Balance zwischen Landwirtschaft und Umweltschutz auf dem Land, einschließlich Forschung, um das Durchfiltern von Nitrat zu minimieren, die Effizienz von landwirtschaftlichen Chemikalien zu optimieren und alternative Strategien für die Landnutzung in Großbritannien zu entwickeln.

Die Forschung des AFRC identifiziert die molekulare Basis "sekundärer Boten", die Signale auf Zellenoberflächen (z.B. von Hormonen) an Mechanismen innerhalb der Zelle weiterleiten, die die erforderliche Aufgabe durchführen. Dies hilft, Zellenfunktion und Funktionsstörung sowie Wachstum und Entwicklung zu erklären und bietet neue Einblicke in Prozesse, die so unterschiedlich sind wie Embryoentwicklung und die Auswirkung von Lithium bei der Kontrolle von manischer Depression. Ein neuer Giftstoff, der durch Forschung an einer respiratorischen Krankheit bei Schweinen identifiziert wurde, wird vermutlich auch zu der Forschung von Zellensignallisierung beitragen. Der Giftstoff ist der stärkste Wachstumsfaktor, den man bis jetzt entdeckt hat. In der Pflanzenbiologie klären wir die Mechanismen von intrazellularen Transportsystemen auf, die für viele Pflanzenfunktionen äußerst wichtig sind.

Was das Gen selbst anbetrifft, berichten wir über die Verwendung von "Antisinn"-Genen, die neuartige Methoden bieten, um den Ausdruck und die Regulierung der Gene in transgenischen Pflanzen zu untersuchen; über wie Genenkodierung für menschliche Antikörper zu einer wirkungsvolleren Therapie gegen Infektionen und Krebsarten führen könnte; und über das Potential, leguminöse Feldfrüchte zu entwickeln, die Schädlingsangriffen gegenüber widerstandsfähig sind, indem natürliche stickstoff-fixierende Bakterien verwendet werden, die mit bakterieller Genenkodierung für Giftstoffe versehen sind, die Insekten töten. Die Protein-Technik bietet das Potential, Enzyme und andere Proteine für spezielle Industriezwecke zu konstruieren, um zum Beispiel bei besonderen pH-Spiegeln zu funktionieren. Wir berichten über unser zunehmendes Verständnis der Struktur/Funktions-Beziehungen in Papaya-Proteasen, einschließlich der ersten Beschreibung der tertiären Struktur von Papaya-Proteinase Omega.

Die Forschung am DAFS-finanzierten Forschungsinstitut Hannah zeigt, daß das Hormonrelaxin, bei dem man zuvor dachte, daß es auf die Eierstöcke oder die Uterus beschränkt war, in der Milchdrüse produziert wird. Wir berichten ebenfalls über die AFRC-Forschung, die dahin strebt, unser Verständnis für die Fürsorge und das Verhalten von Tieren zu untermauern, insbesondere wie Schafe ihre Jungen erkennen und gemeinsame Bande schmieden, ein Gebiet, das offensichtliche Implikationen für die Fürsorge Neugeborener und die Pflege von verwaistem Viehbestand hat.

Der AFRC erhielt weiterhin ein zunehmendes Vertragseinkommen von der Industrie und anderen Quellen, das augenblicklich über £16 Millionen beträgt (siehe Seiten 61–63). Wir arbeiten zur Zeit in Kooperation mit ungefähr 200 Firmen und sollen eine neue Regierungs-/Industrie- Initiative in Höhe von £6 Millionen über den industriellen Gebrauch von Landwirtschaftsprodukten führen und die Britische Technologische Gruppe unterstützt ein großes, neues Programm über Feldfrüchteschutz am AFRC- Institute for Arable Crops Research (Institut für Ackererntenforschung).

Der AFRC baut weiterhin auf seine erhöhte Unterstützung für Forschung und Forschungsschulung in den Fortbildungsanstalten (siehe Seite59–60) auf. Als Teilbestand unserer Strategie, die Forschungsausbildung zu fördern, haben wir eine große Anzahl von Forschungsstipendien gewährt und einen neuen Fünfjahresplan für ein Forschungsstipendium im Anschluß an die Promotion eingeführt. Wir haben auch einen Stipendiumsplan für "neue Untersucher" eingeführt, der dazu gedacht ist, jüngere Forscher in den Anfangsstadien ihrer Karriere zu unterstützen.

UNA BASE CONTINUA DE INVESTIGACION EN EL REINO UNIDO

El AFRC (Agricultural and Food Research Council) provee una fuerte base para la investigación fundamental y estratégica dentro de las ciencias biológicas, lo cual determinará el futuro avance en muchos sectores de primordial interés: en la industria agrícola y alimentaria, las cuestiones relativas al consumidor y conservacionismo, y en la medicina veterinaria y humana.

Las siguientes páginas brindan ejemplos de algunas de las excitantes áreas de investigación corrientes, y muestran en qué modo el AFRC aporta su contribución a dos importantes cuestiones de actualidad: la actitud del consumidor frente a los alimentos, incluyendo investigaciones acerca de la razón por la cual la gente come lo que come, los factores determinantes de la calidad de los alimentos, y estudios fundamentales acerca de la relación entre la dieta, la salud y la etiología de las enfermedades; y el equilibrio entre la agricultura y la conservación de la campiña, incluyendo investigación para minimizar la lixiviación con nitratos, optimizar la eficacia de los productos agroquímicos, y desarrollar estrategias alternativas para el uso de la tierra en el Reino Unido.

La investigación del AFRC está identificando las bases moleculares de los "segundos mensajeros" que transmiten señales en la superficie de las células (por ejemplo, de las hormonas) a los mecanismos que se encuentran dentro de las células que ejecutan la función requerida. Esto está ayudando a explicar la función, disfunción, crecimiento y desarrollo de las células, y ofrece nuevas perspectivas en cuanto a procesos tan diversos como el desarrollo embrionario y el efecto del litio para controlar la depresión maníaca. Resulta muy posible que una nueva toxina, identificada durante la investigación de una enfermedad respiratoria en los porcinos, contribuya a la investigación acerca de la transmisión de señales a las células. La toxina constituye el más potente factor de crecimiento que se haya descubierto. En la biología de las plantas se están dilucidando los mecanismos de los sistemas de transporte intercelular, de vital importancia para muchas de las funciones de las plantas.

A nivel de los genes en sí, informamos acerca del uso de genes "antisentidos" que ofrecen nuevas formas de investigar la expresión y regulación de los genes en las plantas transgénicas; también, acerca del modo en que la codificación de los genes de los anticuerpos humanos podría llevar a una terapia más eficaz para las infecciones y los cánceres; y acerca del potencial de desarrollo de cultivos leguminosos resistentes al ataque de plagas mediante el uso de bacterias fijadoras de nitrógeno natural equipadas con genes bacterianos codificados para toxinas que destruyen insectos. La ingeniería de proteínas ofrece el potencial para el diseño de enzimas y demás proteínas para fines industriales específicos, por ejemplo, para operar con ciertos niveles de pH en particular. Informamos acerca de los avances en cuanto a nuestra comprensión de la relación entre la estructura/función de las proteasas de la papaya, incluyendo la primera descripción de la estructura terciaria de la proteinasa omega de la papaya.

La investigación realizada por el Hannah Research Institute, subvencionado por DAFS, demuestra que la hormona relaxina, que anteriormente se consideraba confinada al ovario o el útero, se produce en la glándula mamaria. También informamos sobre las investigaciones del AFRC dirigidas a reforzar nuestro entendimiento del bienestar y conducta de los animales, en especial, en lo que se refiere al modo en que las ovejas reconocen y se vinculan con su cría, sector de la conducta animal con obvia repercusión en cuanto a los cuidados neonatales y la cría de ganado huérfano.

El AFRC ha continuado atrayendo un creciente ingreso proveniente de contratos con la industria y otras fuentes, el cual en estos momentos supera los 16 millones de libras esterlinas por año (ver páginas 61–63). En la actualidad, trabajamos en colaboración con aproximadamente 200 compañías, y encabezaremos una nueva iniciativa de 6 millones de libras esterlinas del gobierno/la industria para el uso industrial de las cosechas agrícolas, y el British Technology Group está respaldando un nuevo e importante programa para la protección de las cosechas en el Institute of Arable Crops Research del AFRC.

El AFRC sigue desarrollando su incrementado apoyo a la investigación y formación para la investigación en las instituciones de estudios superiores (ver páginas 59–60). Como parte de nuestra estrategia para incrementar la formativa de investigación y el desarrollo de carreras, hemos otorgado una gran cantidad de becas para investigación, y hemos lanzado un nuevo programa becas de post-doctorado con una duración de cinco años. También hemos introducido un programa para otorgar subvenciones a "nuevos investigadores", las cuales están destinadas a apoyar a los investigadores más jóvenes en las primeras etapas de su carrera.

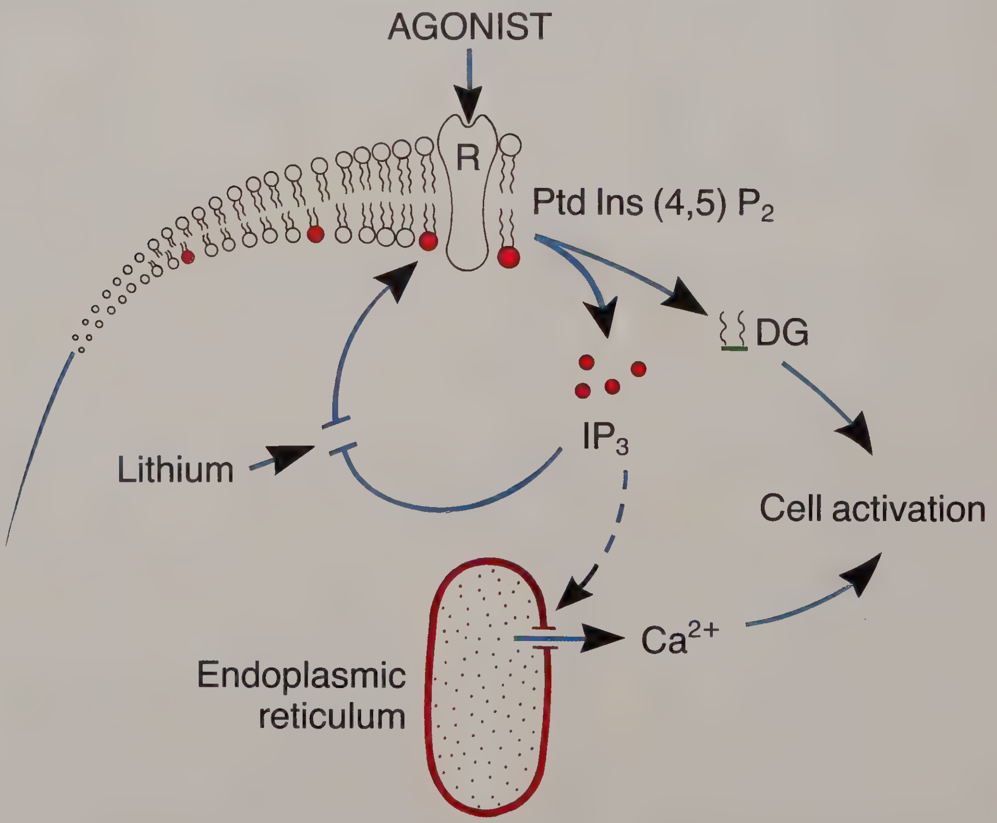
MESSAGES WITHIN CELLS

The signals from hormones and growth factors are relayed through the cell by "second messengers", now being elucidated within the AFRC Institute of Animal Physiology and Genetics Research, including its Laboratory of Molecular Signalling at the University of Cambridge.

The second most cited paper in the World's scientific literature of the 1980s has come from AFRC research on the mechanisms within the cell that control cell function, from moment to moment and at all stages from fertilisation to death. The implications of the work seem limitless: the research is elucidating nervous activity and control, growth and embryogenesis, and some of the processes that cause cells to become cancerous. In more detail, the studies have led to hypotheses that explain, for example, the many effects of lithium, both in controlling manic depression and in causing embryonic malformation (teratogenesis). The mechanisms under study are those that lead to a rise or fall of free calcium within the cell; for calcium is known to stimulate and to be essential for a vast range of cell activities. Interest is focused on processes involving "second messengers", which carry information from the cell surface to particular targets within the cell - in this case, the "pools" where calcium is stored. The second messengers of special interest are phosphates of the sugar-like compound inositol, which in a resting state are bound to lipids in the cell membrane.

The various outside agents that influence and control cell function - hormones, neurotransmitters, growth factors - operate in two main ways. Some enter the cell, and impinge directly upon their target: thus do steroid hormones induce the transcription of genes. Others simply bind with a receptor on the surface of the cell, which then causes a second messenger to be released, which in turn homes in upon the target.

The research on second messengers and calcium release at Cambridge has run in parallel with work in Japan; the two research groups studying two second messenger systems that are closely linked.



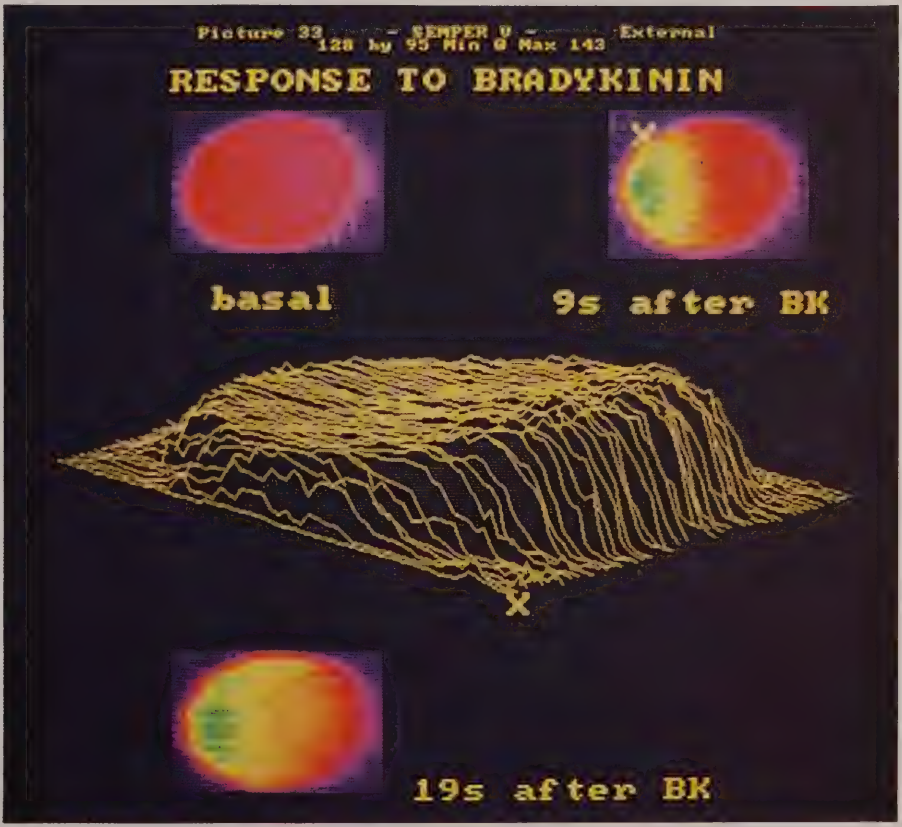
Agonists bind to cell surface receptors (R) to stimulate the hydrolysis of a membrane lipid PtdIns(4,5)P_2 to give the two second messengers, inositol trisphosphate (IP_3) and diacylglycerol (DG). Lithium blocks the reincorporation of IP_3 into the membrane.

In summary, the whole picture is as follows. Bound into the membrane of a typical cell - indeed a component part of the membrane - are lipids that are combined with phosphates of inositol. The most important of them is phosphatidylinositol (4,5)-bisphosphate, PtdIns(4,5)P_2. An external stimulating agent (an "agonist") binds on to a receptor on the cell surface, also part of the membrane. This binding reaction, working through a coupling programme, then causes the enzyme phosphoinositidase (PPIase) to hydrolyse the PtdIns(4,5)P_2. This latter is thus broken down into two components, both of which act as second messengers. One is diacylglycerol, the main subject of the Japanese work, which operates by activating the enzyme protein kinase C, in turn a major determinant of cell growth and division. The other is inositol 1,4,5-trisphosphate which, either in its original form or after conversion to other forms (for this is a highly versatile molecule) releases calcium from one or several of its binding sites, for example in the endoplasmic reticulum. Within this basic inositol mechanism there are many possible variants, involving different kinds of receptor; different forms of inositol phosphates (which perhaps may also operate in combination, to give even more variations); and different sites of bound calcium. Thus, the essentially simple mechanism can in principle operate with boundless versatility, and infinite subtlety; just as a language, with a limited vocabulary, can convey endless shades of meaning.

The Cambridge work has already led to many insights, which help to explain cell function and dysfunction, growth and development. It has long been known, for example, that calcium levels in cells fluctuate. The underlying cause, it now seems, is that calcium ions may travel in waves within the cell: one pool releases its calcium, which stimulates the next, and so on. These waves may travel too from cell to cell, through the gap junction which interrupts the intervening membranes and gives continuity within a tissue. Thus is activity coordinated, both within a cell and within a tissue. Such mechanisms can be seen in action (it seems) in the coordinated (but interruptible) beating of cilia. It now seems, indeed, that correct cell function and coordination is largely determined by the three dimensional geometry of the cell: the precise position of the different calcium pools, relative to each other. The topography of the intact cell is a growing area of study.

Characteristic of this whole area of study is its success in relating short term events to long term. Thus, one hypothesis from Cambridge is that lithium helps to control manic depression - both the over-active and the under-active states - by mopping up inositol within the cell, and so interrupting the synthesis of inositol lipid within the cell membrane. In normal cells, the turnover of inositol lipid in the cell membrane is low, so lithium has little effect on healthy nervous systems. But when the turnover is high (as might be the case in manic depression) the reduction of available inositol damps it down.

A comparable mechanism could operate on the longer time-scale to cause abnormal fetal development, as lithium has long been known to do. Normal development depends on establishing a correct dorsoventral axis; and this in turn seems to depend on creating a chemical gradient, from front to back. Phosphoinositides could well be the basis of such a gradient; and lithium, by damping the turnover of these materials, could reduce the gradient and hence prevent the clear establishment of an axis. ■



Response of a neuroblastoma cell to bradykinin illustrating that IP_3 has induced a localised elevation of calcium as revealed by fluorescent digital imaging microscopy.

ANTISENSE GENES FOR LONG-LIFE FRUIT

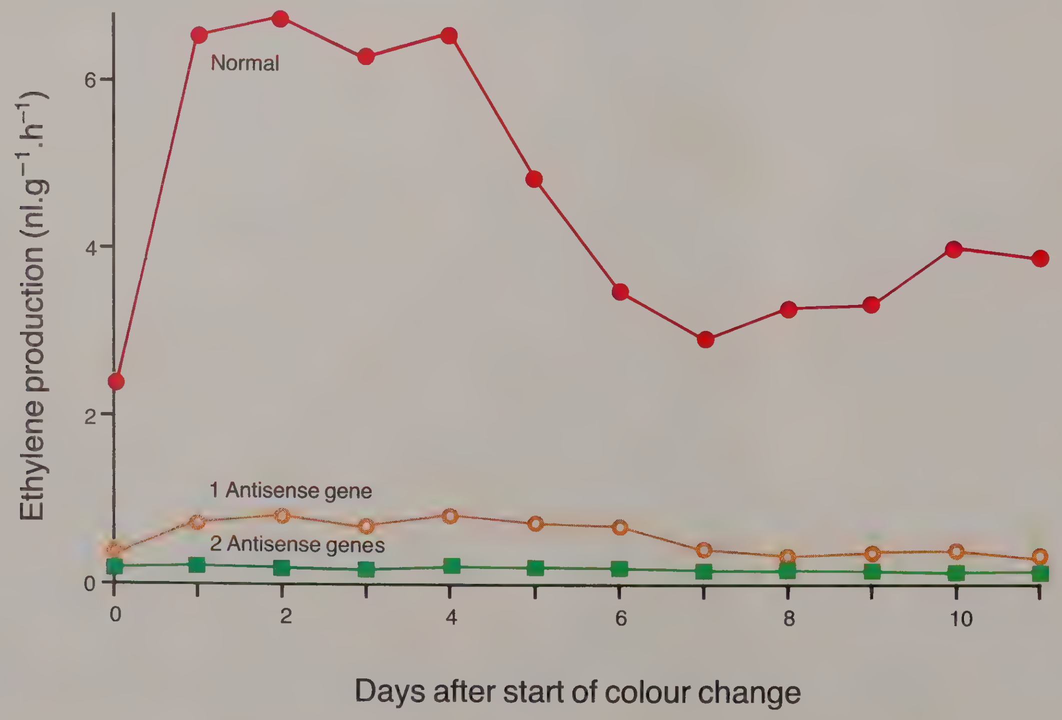
AFRC research at Nottingham University promises to provide fruit that stays ripe but spoils only slowly. More far-reachingly, it offers novel ways of identifying unknown enzymes and their function in the living cell; and of investigating gene expression and regulation. The research involves the use of "antisense genes" in transgenic plants.

Antisense genes are stretches of DNA that have been clipped out of the double DNA strands, cloned, and then reinserted using *Agrobacterium* plasmids, but in reverse. The original genes are left intact; so the transformed diploid cell now contains two copies of the original gene, plus one copy of this inverted stretch of gene.

The enzyme that transcribes DNA into messenger RNA (mRNA) now makes a copy of the normal genes; but it also makes an mRNA transcript of the inverted piece of DNA - which, of course, is a reversed version of the normal transcript. These reversed transcripts interfere with the transcription of the normal mRNA, and/or with its translation into protein. Thus, antisense genes inhibit expression of the normal genes from which they were originally contrived. They inhibit the action of specific genes by virtue of the interaction of complementary base sequences in the sense and antisense RNA strands.

Antisense genes are inherited stably, and behave in normal Mendelian fashion. Thus, when transformed plants that each contain an antisense gene are crossed, 25 per cent of the offspring contain no antisense gene, 50 per cent contain one copy and expression of the corresponding gene is partially inhibited; and 25 per cent contain a double dose of the antisense gene. In these, research at Nottingham has shown that expression of the normal gene can be suppressed by 99 per cent. Such efficient, targeted expression is of enormous theoretical and practical value - especially as the normal genes are left intact, and the antisense genes can be removed by breeding to restore a normal line!

Much of the work at Nottingham (previously financed in part by SERC in conjunction with ICI - whose involvement continues) has focused on the enzymes and genes involved in the ripening of tomatoes; plants that are readily transformed, and obviously of great commercial value. Earlier work showed that the enzyme polygalacturonase (PG) was synthesised during ripening in response to ethylene; and the gene that codes for PG was identified and sequenced. In tomatoes that contain a PG antisense gene, mRNA



Ethylene production during ripening of normal tomatoes compared to transgenic fruit with 1 or 2 pTOM13 antisense genes.

for PG is almost absent, and so, accordingly, is PG itself. Such transformed fruit ripen normally, developing colour and aroma and producing ethylene, but the degradation of their cell walls that would normally be brought about by PG, is inhibited. Thus the fruits take a long time to over-ripen, and spoil. Clearly, this principle could be applied more widely, for example, to suppress genes that produce toxins.

Recent work illustrates the investigative value of antisense genes. It began with identification of a gene called pTOM13 which was expressed very rapidly (so that mRNA accumulated) when a plant was wounded. This expression correlated with production of ethylene, suggesting that the gene was involved in producing one of the enzymes responsible for ethylene synthesis. This was an exciting possibility, because ethylene is involved in the control of many plant functions, but the genes encoding enzymes that catalyse production have not been identified.

The Nottingham scientists prepared an antisense gene to pTOM13; and showed that plants transformed with it produce little ethylene (or the mRNA that correlates with ethylene production) in response to wounding, or in ripening. The inhibition was greater in plants containing two copies of the antisense gene (see Figure). For various reasons (including results from IPSR John Innes) the Nottingham group now hypothesise that the enzyme coded for by pTOM13 is ACC oxidase, an enzyme never before purified, which carries out the final step in ethylene production.

The ability to control ethylene production is expected to be of immense value in studying processes such as fruit ripening, senescence of leaves and flowers, and abscission of plant organs. It may also provide a means of changing these processes, which have an important influence on plant productivity and quality. ■

PLANT MOLECULAR BIOLOGY (PMB) PROGRAMME

The use of antisense technology to elucidate plant gene function is just one component of AFRC's £14M co-ordinated programme in plant molecular biology which involves researchers in universities, polytechnics and institutes. This initiative, under the overall co-ordination of Professor Don Boulter of the University of Durham, is organised within two interacting components: - a general programme of over 70 projects, including some which are university-university and university-institute collaborations; and a programme of more than thirty projects on the molecular biology of *Arabidopsis,* a small cruciferous plant whose simple genome makes it an ideal model for studies on gene function and regulation.

Topics under investigation within the PMB programme include: the genetics of the regulation of metabolic pathways, including, for example, the isolation and characterisation of genes encoding for key synthetic enzymes, and hormonal and developmental control of gene expression; the use of gene transfer techniques, for example, to develop antiviral resistance mechanisms; genome organisation and chromosome structure, for example, using *in situ* hybridisation to study the physical organisation of DNA sequences on plant chromosomes; and the molecular basis of signalling, for example, stigma-pollen recognition and the mechanisms involved in self-incompatibility.

Regular meetings of grantholders supported under the PMB programme help to ensure efficient use of resources and information exchange. For example, within the *Arabidopsis* programme, resource centres are being established on gene libraries and database (AFRC Institutes of Plant Science Research), cDNA libraries (University of Essex) and seed collections (University of Nottingham). ■

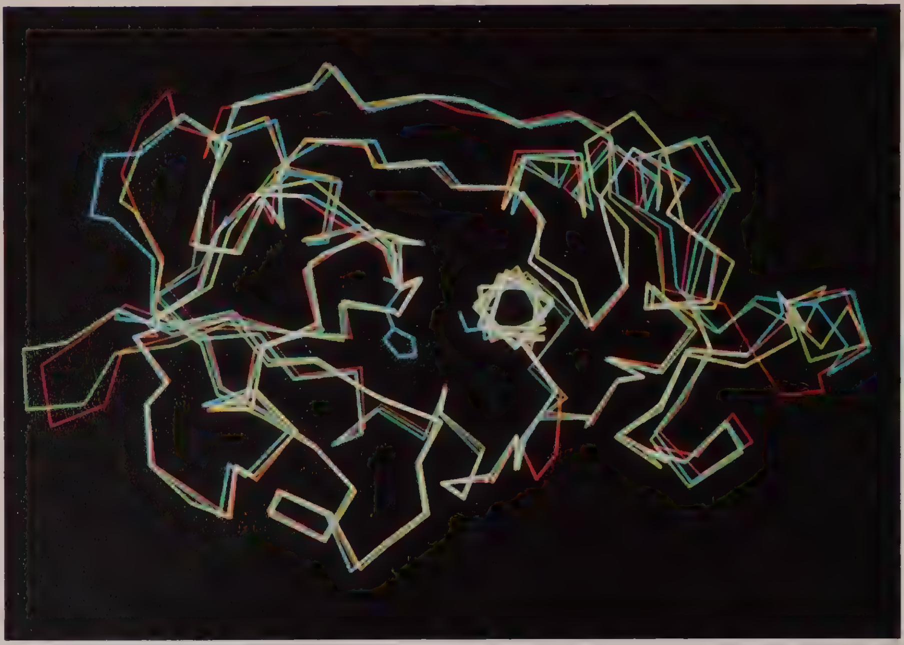
Round table discussion on programme co-ordination, at a meeting of PMB grantholders (left to right) Dr Mulligan, co-ordinator of the Arabidopsis *programme; Professor Boulter, overall co-ordinator; Professor Leaver, co-ordinator of the general programme; and Dr Maplestone, of AFRC Central Office's Higher Education Branch.*

PROTEIN ENGINEERING: BETTER ENZYMES FROM PAPAYA

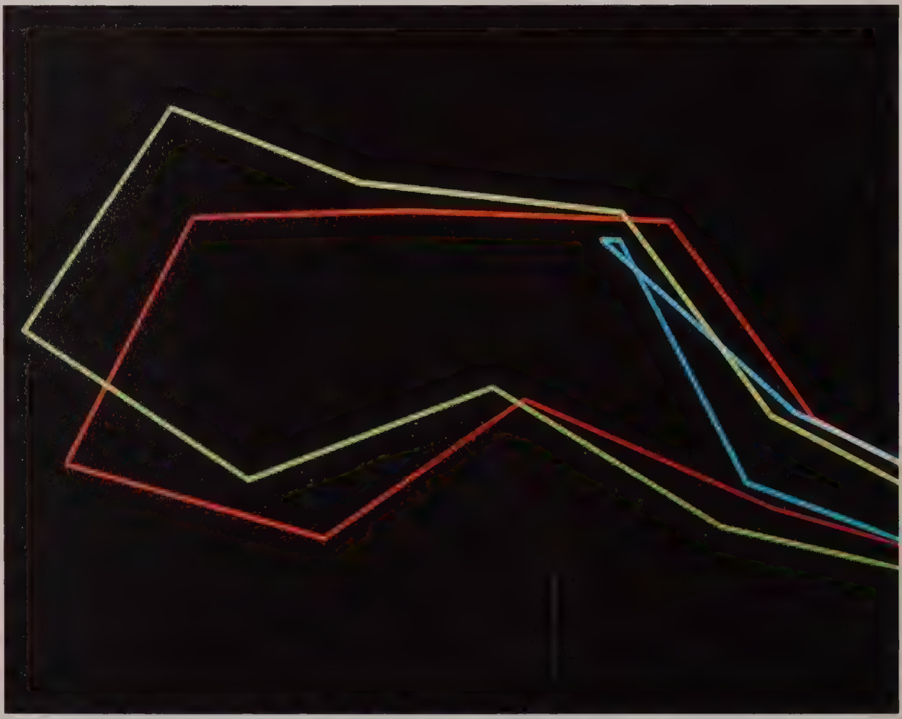
Cloning and manipulation of the proteases from papaya has immediate commercial significance. More crucially, research is elucidating the relationship of protein structure and function - which eventually will make it possible to design enzymes to order.

Enzymes are complex proteins, and their properties depend on the sequence of amino acids in their chains (their primary structure) and on how those chains are folded into a three-dimensional form (tertiary structure). Researchers at the AFRC Institute of Food Research, in a Linked Research Group with Birkbeck College, London, and in collaboration with scientists at the universities of Oxford, Sheffield and Kent, are working to understand the relationship between primary and tertiary structure - why a particular sequence folds as it does; and between primary and tertiary structure and function - why a particular enzyme molecule should do the things that it does, and require specific conditions to operate efficiently. Such knowledge underpins the emergent science of "protein engineering", which will enable proteins of all kinds (including enzymes) to be designed at will, to carry out novel functions, or to operate in prescribed conditions. Much of this AFRC research so far has focused on the cysteine protease enzymes derived from the latex of papaya: enzymes that already have a wide range of industrial uses and are also of great fundamental importance.

Papaya latex contains several proteases, of which the best known is papain, but of which the most abundant is papaya proteinase omega. Papain and pp omega are highly active proteases which produce polypeptides or peptides rather than free amino acids. For many applications in the food industry this is preferred to hydrolysis with mineral acid, which is random, produces more free amino acids and leaves salt in the food when



Alignment of α carbon backbones of papain (blue), papaya protease omega (red) and actinidin (yellow). Co–incident backbone is white.



A surface loop of papain (blue), papaya protease omega (red) and actinidin (yellow) showing a four amino acid deletion in papain.

neutralised.Papain in particular is used in industry for clearing beer and has been used for tenderising meat. But papain and pp omega are both good "blockbusters", capable of breaking down a wide range of proteins and could in principle replace the chemical methods (which employ cheap forms of hydrochloric acid) that are used extensively in snack food and special diets.

The IFR researchers in collaboration with some university groups are concentrating mainly on the enzymes themselves; on the structure; on cloning; on manipulation of structure; on relating structure to function; and, for example, on the creation of novel pp omega that can operate in more acid conditions, which industry would prefer because at low pH bacterial contamination is reduced.

Using the new Xentronics area detector, funded by AFRC, the IFR scientists have resolved the three-dimensional structure of papain (to a resolution of 1.6 angstroms). The detector collects x-ray diffraction data quickly and accurately. Thus, x-ray crystallographic studies that conventionally took years, can now be completed in weeks. The 3D structure of pp omega has been resolved to 1.9 angstroms, from data collected by the SERC synchrotron radiation source at Daresbury: the first ever description of the tertiary structure of pp omega, and the first protein structure to be solved with the Daresbury machine.

At the same time, study of the enzyme's DNA structure has shown that papain consists of 212 amino acids, preceded by a pro-sequence of 133 amino acids, which may be essential for correct folding. The gene that produces the entire structure has been isolated and cloned in the filamentous fungus *Neurospora crassa*. *Escherichia coli* is a more conventional vector but expression of papain kills that particular bacterium. In addition, one of the *Neurospora* genes is promoted by a sequence that is activated by acetate; and if this promoter is attached to a foreign gene that is introduced to *Neurospora*, then its expression can be controlled simply by the presence or absence of acetate in the culture medium.

Research to relate structure to function in both papain and pp omega - research helped by comparing and contrasting the two - has focused in particular on the active site of these enzymes; on mechanism, and on the possibility of improving stability. In cysteine proteases the active site is electrostatically charged: a cysteine, carrying a negative charge on its sulphur, is positioned opposite a positively charged histidine. This charge is essential to the activity but is normally maintained in the pH range 4.0 through 8.0. When the nature of charge stabilisation at the active site is fully revealed, then it should be possible to create mutant forms of the enzyme (by substituting different amino acids in key positions) and so produce activity at low pH values. This will create new forms of pp omega that can operate at pHs that are too low to sustain contaminant bacteria - of enormous potential value to industry. ■

COMPUTER ANALYSIS OF PROTEIN SEQUENCES

The explosive growth of protein sequence data greatly outstrips detailed information about the 3-dimensional structure of proteins. An AFRC Linked Research Group between the University of Leeds and the John Innes Institute is developing and exploiting new computing technologies to analyse protein sequences so that predictions can be made about protein structure, and so that functional similarities between different proteins can be readily identified. This information is essential to answer questions about the relationships of proteins and to identify the location of their critical residues, and thus sites for potential modification e.g. by mutagenesis. It is of particular value in determining the function of newly characterised proteins (often deduced only from translation of DNA sequences).

Conventional database scanning programmes can rapidly reveal strong sequence similarities. However, similarities of structure and interactions are often very weak. The Leeds scientists, by integrating sequence and structure data, have devised analyses which provide additional information, for example, the recognition of sequence/structural patterns characteristic of motifs important in molecular interactions of proteins - and the use of pattern discriminators for predicting functions of parts of proteins.

The Leeds-John Innes collaboration has focused on protein sequences that are important in the molecular biology of plants and their pathogenic and symbiotic bacteria and viruses. Over fifty protein sequences from *Pisum, Antirrhinum, Rhizobium, Xanthomonas, Streptomyces,* geminiviruses and caulimoviruses have been analysed. The interaction of plant virus proteins with a range of molecules involved in their infectivity, both with plant components and insect vectors is one area of study. This includes, for example, analysis of the possible role of some coat proteins in cell-to-cell and long range spread of viruses, and analyses of aphid transmission proteins.

By using these advanced computer analyses, many processes of protein recognition and interaction that are poorly understood at present should become amenable to investigation by molecular genetic and protein engineering techniques.

As a result of this Linked Research programme, an extensive protein database and an associated package of programmes for analysing amino acid sequences has been placed at the AFRC Computing Division at Harpenden. ■

HUMAN ANTIBODIES FROM NOVEL SOURCES

A novel method of producing human antibodies could lead to more effective therapy for a wide range of intractable human infections and cancers.

Many human diseases, including cancers, infections such as AIDS, and some autoimmune disorders, might in principle be treated by administering antibodies, to attack the offending cells or pathogens. Usually, however, no human antibodies are available; and if antibodies from other species are given - for example, from mice - then these, being foreign protein, themselves provoke an immune response, which can endanger the patient. Scientists at the AFRC Institute of Animal Physiology and Genetics Research and the MRC Laboratory of Molecular Biology at Cambridge have now transferred genes that code for human antibodies into mouse cells, and shown that these can then produce a human antibody repertoire. Mouse immune cells transformed in this way can then be "immortalised" with virus or by fusing with tumour cells to form hybridomas, which can be cultured to provide a constant source of human antibody. It should be possible, in principle, to establish sources of human antibody against a wide range of antigens - including some for example as may be found on human cancer cells, that the human immune system itself does not respond to.

Each antibody, whatever the species, consists of four protein chains - two heavy (long) and two light (short). The two heavy chains lie side by side, but divert part way along their length, to form a "Y"; and the light chains lie along the arms of the Y. The stalk of the Y, and the bases of the arms, have a constant structure, which depends on the class of antibody and the species. The distal regions of the arms are variable, and give each antibody a structure specific to the particular antigen it is designed to attack. Different genes, lying separate on the chromosome, code for different parts of the antibody; their exact arrangement depends upon the kind of antigen being catered for, and the DNA segments are shuffled into the appropriate sequence as the immune cells (lymphocytes) proliferate.

AFRC and MRC scientists have obtained the relevant genes from human cells, and inserted them into fertilised mouse eggs. The antibody producing cells from these mice secrete human antibodies which may be directed against a variety of antigens; and hybridomas incorporating the transformed mouse immune cells also make human antibodies.

This work, though still at an early stage, promises to overcome several major obstacles in antibody therapy. One immediate task is to produce mouse lines that produce a higher proportion of human antibody; preferably, indeed, to suppress production of mouse antibody altogether, so that only human antibody is produced. Libraries of transformed mice cells will then be made that produce a wide repertoire of human antibodies - including some that humans cannot themselves produce.

This work is the subject of a patent, and is funded by the Leukemia Society of America, and by the Medical Research Council. ■

MAKING LEGUMES RESISTANT TO WEEVILS

Leguminous plants carry symbiotic bacteria (rhizobia) in their roots. Transgenic rhizobia, fitted with genes to make toxins, could give the crops resistance to some insect pests.

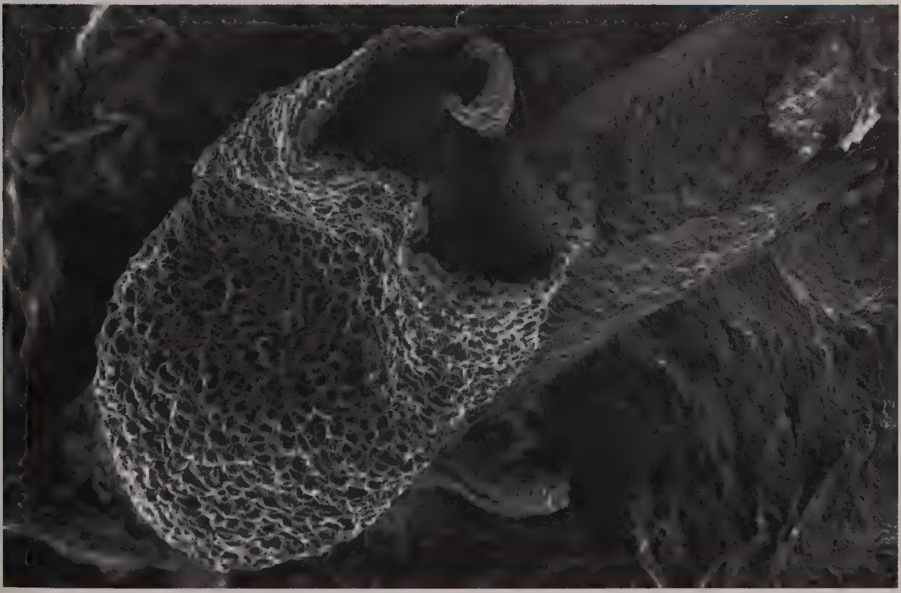
Weevils of the genus *Sitona* attack the nodules on the roots of leguminous plants - nodules that contain *Rhizobium* bacteria which "fix" atmospheric nitrogen and nourish the plant. Scientists at the AFRC Institute of Grassland and Environmental Research, Welsh Plant Breeding Station have now transferred genes from a bacterium which produces an anti-*Sitona* toxin into *Rhizobium;* and thereby hope to produce forms of leguminous crops that resist *Sitona* attack.

The bacterium that produces the delta-endotoxin and supplies the relevant gene is *Bacillus thuringiensis.* Different subspecies of *B. thuringiensis* produce different toxins, active against different orders of insects: moths, flies, and so on. The subspecies that produces anti-beetle (including anti-weevil) toxin is *B.t.tenebrionis.*

AFRC research has already shown that rhizobia containing the *tenebrionis* toxin gene are indeed active against *Sitona.* Research now aims to enhance the expression of the gene, and thus increase the toxicity. One approach is to attach a promoter to the 5-prime end of the DNA sequence of the toxin gene. A promoter is a sequence of DNA that controls the expression of genes downstream to it. To be effective, promoters must of course be active within the cell in which they occur, or are introduced. Candidate promoters are known within *Rhizobium* itself, which control the activity of the nitrogen fixing ("nif") genes.

If this approach works, it will mean that the toxin is produced only where

White clover plants with foliage eaten by the clover weevil Sitona *spp.*



it is needed: in the nodules. However, the particular promoter isolated so far is from *Rhizobium trifolium,* which specifically nodulates clover; and if it is to work within rhizobia that nodulate other legumes such as peas or beans, it may need modification.

Another approach is to attach the toxin gene to a promoter that is known to be active within plants, and then put it directly into the host plant. AFRC researchers are at present using *Lotus corniculatus* (birdsfoot trefoil) as an experimental host; while the promoter is from the cauliflower mosaic virus, which is known to be active in plants. A nopaline synthase terminator from *Agrobacterium,* which is known to be active in plants, completes the gene "cassette"; which will then be introduced into *Lotus* via *Agrobacterium,* which of course is a standard vector. The possible theoretical problem here is that the *B. thuringiensis* gene, being bacterial (prokaryotic) in origin, may not work well in a plant (eukaryotic) cell. It may need modification to enable it to do so.

A broader problem, when the present tasks are complete, is to develop transformed strains of *Rhizobium* that can compete in the field; particularly relevant in a country like Britain, where wild strains abound. So far, worldwide, there are no transformed strains of rhizobia that are agronomically useful. Another possible challenge, is to develop strains that will resist attacks by nematodes.

AFRC scientists are planning to collaborate in this work with Dr Jens Stougaard Jensen, of the University of Aarhus in Denmark. ■

Scanning electron micrograph showing a root nodule from white clover eaten by larvae of the clover weevil Sitona *spp.*

WHAT MAKES A EWE A GOOD MOTHER?

Maternal bonding depends both on maternal feelings, and on recognition of the appropriate offspring. The physiological basis for both is being elucidated.

Ewes - like most animals apart from primates - do not behave maternally towards youngsters except when they have just given birth. Then they generally become fiercely attached to their own offspring but continue to reject or attack others. Collaborative work at the AFRC Institute of Animal Physiology and Genetics Research, Cambridge and the University of Cambridge (through an AFRC research grant) is revealing the basis of maternal feeling and behaviour, and why it is generally directed only at the animal's own baby. This research is of great fundamental significance in helping to elucidate a crucial area of animal behaviour and survival strategy. It also has immediate practical relevance, for example in helping shepherds to foster orphan lambs on to ewes. More broadly, the work should help in conservation of endangered species by overcoming the mothers' reluctance to look after their offspring that is often found in captive breeding. The work is partly supported by a commission from MAFF.

AFRC research over the past five years has shown that maternal behaviour, and bonding to one particular lamb, is induced and stimulated by two main factors: hormonal changes of pregnancy and the stimulation and dilatation of the cervix and vagina during parturition itself. This collaborative research (which also involves a group at INRA in France) has confirmed the need for this stimulation: maternal behaviour and bonding are eliminated, for example, if lambs are delivered by caesarian section or following epidural anaesthesia. On the other hand, manual stimulation and dilatation of the cervix just after birth will strengthen the ewe's maternal bond, or induce a bond in an animal that has rejected its offspring. In humans, maternal bonding clearly has broader psychological and social foundations and is not significantly affected by caesarian or epidural anaesthesia birth.

Smell is the principal means by which ewes can identify their own offspring; the physiological basis and its implications for fostering animals and in conservation of endangered species is being elucidated.

The vaginal-cervical stimulus operates at least in part by inducing release of the peptide (proteinous) hormone, oxytocin. Stimulation causes blood levels of oxytocin to rise: and oxytocin in the blood is known to stimulate contractions of the uterus during labour, and the ejection of milk *post partum*. Vaginal-cervical stimulation also causes release of oxytocin within the brain. Oxytocin is the only substance known that can induce maternal behaviour in an animal that has not just given birth. But it is not the only important hormone: the brain's own opiates, the endorphins, also play a significant part.

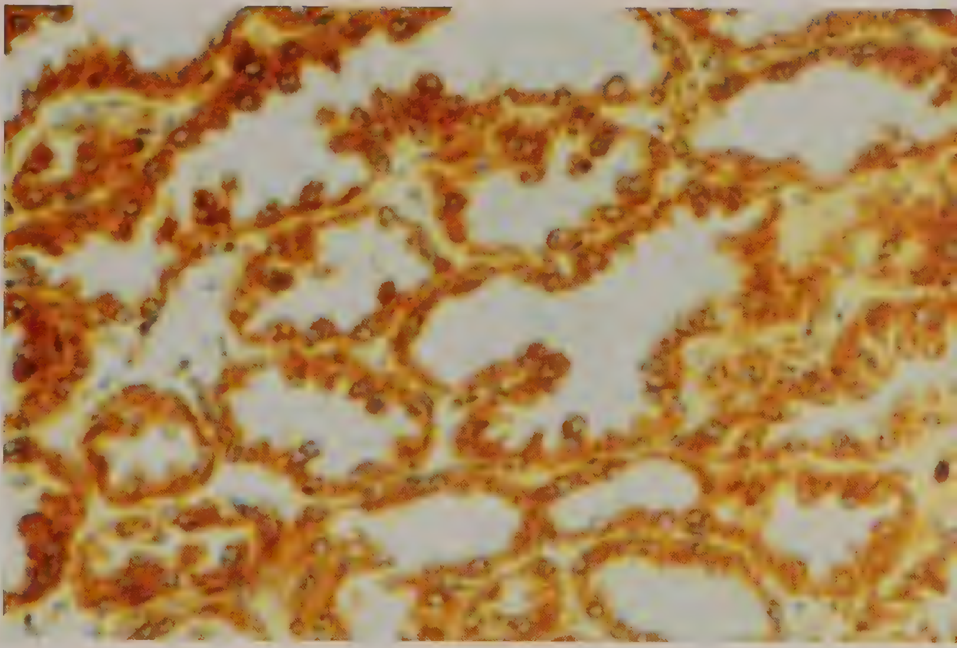
Why, though, does the animal that has just given birth bond so specifically to its own lamb, but continue to reject others? Smell is the principal guide. Evidence so far suggests that at birth, some olfactory bulb cells in the brain that would normally respond primarily to the odours of food, switch their allegiance, and begin to respond mainly to the smell of lamb's wool. Early evidence suggests a preference in these cells for the smell of the ewe's own lamb.

These findings suggest a possible method for fostering orphaned lambs, and it has been shown that with appropriate stimulation, ewes can be encouraged to adopt new lambs in addition to their own. This could be a practical technique for shepherds in the field: more effective and less messy than dressing an orphan lamb in the skin of a ewe's own dead lamb, for example. ■

RELAXIN IN THE MAMMARY GLAND

The presence in the mammary gland of a hormone previously thought confined to the ovary or uterus, raises fundamental questions of mammalian biology - and suggests a possible new approach to understanding changes associated with breast cancer.

Since 1926 the hormone relaxin has been known to produce essential changes that presage birth: relaxation of the pelvis, and of the uterine cervix. It has been clear for many years, too, that the hormone is produced in endometrial cells of the uterus or in the ovary, depending on the species. Research at the DAFS-funded Hannah Research Institute, in conjunction with the University of Hawaii, now shows that relaxin is also produced in the mammary gland, both in late pregnancy and during lactation. The significance of this new finding could be profound. Mammary relaxin may, for example, serve to communicate information from mother to infant - but if so what, and why? At another level, relaxin dysfunction could play a part in the aetiology of breast cancer; and some of the ill effects of mastectomy might be brought about in part by the loss of the hormone.



Mammary gland section from a lactating guinea–pig immunostained for relaxin. Note the denser brown immunostaining in the secretory cells lining the alveoli of the gland.

Circumstantial evidence led Hannah researchers to suspect that the mammary gland might be producing relaxin. First, pregnancy and birth do not always run smoothly in animals that have been mastectomised - suggesting that intact animals normally send some essential signal from the mammary glands. Secondly, the things that tend to go wrong seemed to occur in late pregnancy, and to include a failure of pelvic or cervical relaxation; suggesting a shortfall of relaxin. One of the world's principal centres of relaxin research is the University of Hawaii; and scientists there, prompted by the Hannah, used immunocytochemical techniques (antibodies attached to dyes) to show that the mammary gland does indeed produce a relaxin-like molecule.

Mammary relaxin and endometrial relaxin peak at different times. Thus, in mid pregnancy, both sets of gland cells produce some relaxin. In late pregnancy, mammary content approaches zero, while endometrial content is very high. But in lactation, mammary output is at its highest, while endometrial output falls. The initial observation - that the mammary gland might be producing a relaxin-like signal in late pregnancy - is thus complicated, for the gland's relaxin output at that time is low; and if there is an essential signal from the mammary gland at that time, then it may not be relaxin that is initiating it. On the other hand, the presence of relaxin in the mammary gland, and its particular prevalence in lactation, opens many new possibilities.

For one thing, lactating mothers are known to convey a great deal of information to their suckling young. The nutrient content and volume of the milk is itself informative, about the general state of the environment. The mother's own maternal behaviour clearly influences later development. Information is transmitted pheromonally, probably in both directions. Relaxin, in milk, may convey yet more information; for example about possible future maternal investment in suckling, and hence in preparation for weaning. This has yet to be investigated.

On a quite different tack, relaxin is a known growth factor. The Hawaiian scientists are now exploring its possible involvement in tumour growth, both malignant and non-malignant.

Present work at the Hannah continues to focus on the nature of the mammary signal in late pregnancy; on the possible local effects of mammary relaxin, on the mammary gland itself (does it help to promote ejection of milk, for instance?); and on the influence of mammary relaxin on various organs. ■

NOVEL TRANSPORT SYSTEMS IN CELL VACUOLES

Plant cell vacuoles store a vast range of materials that the plant needs - or wants to be rid of. Studies of the pumping mechanisms could lead to many kinds of crop improvement.

In most living plant cells the most conspicuous organelle is the vacuole; a great sac filled with water that contains active enzymes and a variety of stored and waste materials, both organic and inorganic, all enclosed within a membrane known as the tonoplast. The vacuole is involved in many plant functions including growth and senescence, and also enables some plants to resist nutritional stresses such as mineral deficiency or saline excess. Work at the AFRC Institute of Arable Crops Research, partly in collaboration with the University of York, is now elucidating the transport mechanisms at the tonoplast, which underpin these functions. When these mechanisms are understood, they might be controlled; and special tonoplast-dependent qualities of wild plants might be transferred into crops.

Work at Rothamsted has focused on two kinds of chemical pump, located in the tonoplast, which have primary roles in shifting mineral ions or organic molecules in and out of the vacuole. One is an ATPase; an enzyme which hydrolyses ATP, to release energy. The other is an inorganic pyrophosphatase. The two enzymes use the energy they release by hydrolysis of their substrates to pump protons (hydrogen ions) from outside the vacuole (that is, from the cytoplasm) to the inside. In doing this the pumps create electrical potentials and pH gradients across the membrane; the pH inside the vacuole is normally around 5. These gradients in turn provide the driving force for the passage of other inorganic ions and organic materials across the tonoplast either into the vacuole or back into the cytoplasm.

AFRC research has also helped to show that the ATPase belongs to a newly-identified family of ATPases that are common to the intracellular membranes of animals and fungi, as well as plants. The present studies result from the success of earlier work, which made it possible to isolate vacuoles intact, as complete sacs; and then to separate the pumps from their membranes with detergent to allow them to be purified for further studies. A current problem is why the plant tonoplast - uniquely - contains a pyrophosphatase pump, as well as an ATPase. One hypothesis is that the pyrophosphatase pump can work in two directions - driving protons out of the vacuole as well as in. In one direction the pump would consume pyrophosphate but in the other it would synthesise it and this could mean the pump has an important role in controlling cytoplasmic pyrophosphate which is now recognised as an important plant metabolite. This theory is, however, not proven.

The vacuole, with its surrounding tonoplast, may in general be seen as a survival device. It helps the plant - an organism unable to move out of trouble as an animal can do - to remove potentially harmful ions or organic molecules out of the cytoplasm, so that they do not interfere with general metabolism. These materials may be permanently sequestered, essentially as waste materials; or they may simply be left in store, to be used later. In some cases, the materials stored in the vacuole serve secondary functions, for example as pest repellents.

Vacuoles isolated from the storage root of red beet. They are filled with a water-soluble red pigment, the presence of which confirms that the vacuoles have remained intact.

Thus, some halophytes are able to tolerate salt because they can pump surplus sodium into their vacuoles. Tolerance of mineral deficiency may involve utilisation of nutrients stored in the vacuole and there is evidence that this occurs in potassium deficiency. The vacuole may also act as a temporary storage site. Sugar beet stores sucrose in its vacuoles, for use later. Plants that practice the particular form of photosynthesis known as CAM (crassulacean acid metabolism), which is an adaptation to desert conditions, accumulate large and potentially harmful amounts of malic acid during the day, which they keep out of harm's way in their vacuoles, and metabolise at night. Senescence involves the breakdown of Rubisco, one of the key enzymes in photosynthesis, and the principal protein in leaves; and the vacuole is involved in its hydrolysis.

Clearly, the physical mechanisms that underpin all these abilities and properties - the tonoplast pumps - could in principle be influenced by chemical agents, or, more permanently and satisfactorily, by identifying the genes that underlie those pumps, and perhaps transferring those with particular qualities into crops. This could be a way to create saline-resistant cereals, for example, of great relevance to the Third World; or beets that can store more sugar; or wheat in which senescence of the flag leaf is delayed, and yield of grain increased. ■

THE WORLD'S MOST POTENT GROWTH FACTOR

Research on a respiratory disease of pigs has identified a toxin that promotes cell growth 300 times more powerfully than its nearest rival.

Atrophic rhinitis of pigs, which deforms the snouts of growing animals and sometimes reduces weight gain, re-emerged in the early 1980s as a serious clinical problem in Britain and Europe. Fundamental studies at the AFRC Institute for Animal Health, partly funded by MAFF, have laid the foundations for a new generation of safe and effective vaccines. But more far-reachingly, they have also revealed a mechanism of disease that in crucial aspects is unlike any other. It involves production of a bacterial toxin that is the most potent mitogen (promoter of cell growth and division) yet discovered - and one with a unique mode of action. This mitogenic toxin will be of enormous value in further studies of normal and abnormal cell growth.

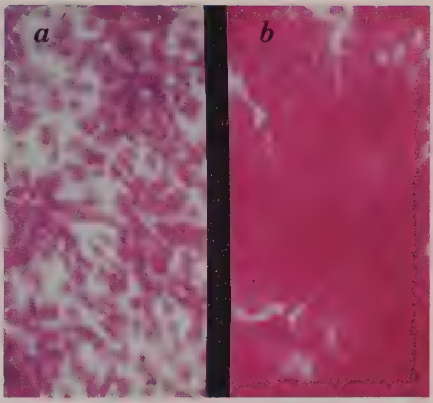
In atrophic rhinitis, damage is most evident in the turbinate bones of the nose, which warm and humidify incoming air. Many pathogens have at times been suspected, but two emerged as outstanding candidates: *Bordetella bronchiseptica* and *Pasteurella multocida*. Research has shown that although some strains of *B. bronchiseptica* can produce some disease, the full-blown and persistent form is caused particularly by isolates of *P. multocida* which produce a toxin.

The IAH scientists have cloned the toxin gene and purified the toxin. The purified recombinant toxin, a protein of molecular weight 145,000 belongs to that very rare category of bacterial toxins capable of producing all the signs of the natural disease by themselves. Others include botulinum, tetanus and cholera toxins. The *P. multocida* toxin is also interesting for other reasons. Firstly, it is lethal in extremely low doses. Secondly, atrophic rhinitis involves not only the primarily destructive changes in the nose bones but also proliferation of some cells. So the toxin has both destructive and growth promoting effects although it was initially thought that the proliferation was secondary to destruction and represented tissue repair.

To explore the mode of action, AFRC scientists are collaborating with the Cell Growth and Division Laboratory of the Imperial Cancer Research Fund (ICRF). The *Pasteurella* toxin was applied to the cell line, Swiss 3T3 fibroblasts, which have been used a great deal in cell growth studies.

Unexpectedly, the *Pasteurella* toxin was an extremely potent mitogen: 300 times more effective than platelet derived growth factor (PDGF), hitherto the most potent mitogen known; and 1000 times more potent than bombesin. Unlike PDGF and bombesin the new toxin produced the maximum growth of which the cells were capable. PDGF, bombesin, and the *Pasteurella* toxin are the only growth factors which by themselves are able to cause Swiss 3T3 cells to resume growth. Finally, both PDGF and bombesin stop acting as soon as they are washed out of the medium. The mitogenic effect of the *Pasteurella* toxin persists long after it is removed.

That a promoter of cell growth should lead to destruction of the turbinate bones seems paradoxical. However, bone growth is controlled by a balance between osteoblasts, which lay down bone; and osteoclasts, which resorb it. The osteoclasts are controlled by messengers from the osteoblasts. The AFRC and ICRF scientists postulate that in atrophic rhinitis, the *Pasteurella* toxin causes the osteoblast precursor cells to proliferate thereby preventing differentiation into mature osteoblasts. Functional osteoblasts are thus depleted (as the old ones die and are not replaced). This reduces bone growth, and also reduces the control of the osteoclasts. The net effect is bone destruction.



Swiss 3T3 cells **(a)** *untreated and* **(b)** *72 hours after the addition of toxin.*

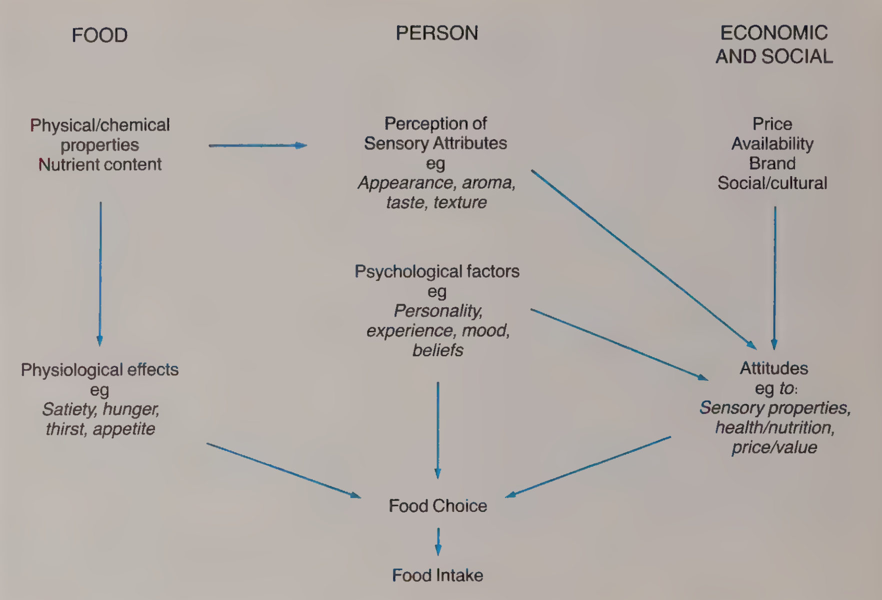
Evidence so far suggests that the mitogen attaches to a receptor on the target cell surface, and that part or all of it then enters the cell. This would make it unique among known growth factors, which generally remain on the cell surface. Thereafter the *Pasteurella* mitogen seems to operate via secondary messengers, which are chemical signals within the cell, as do other mitogens. However, cell growth and division is activated by changes in a complex network of different secondary messengers and it now seems likely that the use of this toxin will lead to the discovery of new signalling pathways.

There are many implications of this work. First is the biotechnological production of a modified "toxoid" molecule that would be antigenic but not toxigenic: in other words, an effective but extremely safe vaccine. Secondly, the recombinant gene can be modified to help analysis of the toxin's mode of action, and more fundamentally, the mitogen is a new tool for investigating both normal and abnormal cell growth and control as well as for studying the control of bone remodelling. ■

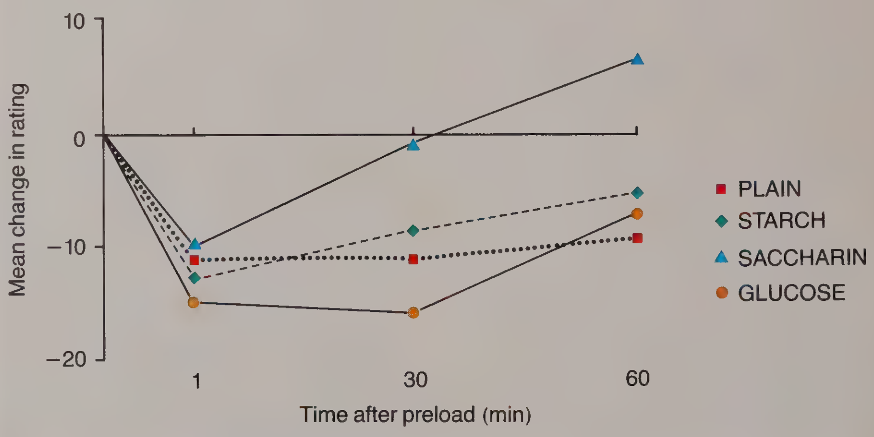
FOOD QUALITY AND THE CONSUMER

Increasing emphasis is being placed by consumers, Government and food manufacturers alike on the "total quality" of food, as well as upon the efficiency of its production. This requires consideration to be taken of the many factors that determine food acceptability and of the complex relationships between diet and health.

AFRC-supported researchers in universities and at the AFRC Institute of Food Research are developing improved methods for assessing consumer appreciation of quality, and for identifying the determinants of sensory quality in individual foods. A new initiative in psychobiology has been established to explore the relationships between food consumption and a number of outcome measures including mood, hunger and satiety, and food preferences. The study of food choice examines the myriad influences upon consumer selection of particular food items, a process which is ultimately critical in determining overall diet. A better understanding of these factors will help to improve public health nutrition guidelines and intervention programmes, and aid manufacturers in development of foods with high consumer acceptance.


FOOD
PERSON
ECONOMIC AND SOCIAL
Physical/chemical properties
Nutrient content
Perception of Sensory Attributes
eg
Appearance, aroma, taste, texture
Price
Availability
Brand
Social/cultural
Psychological factors
eg
Personality, experience, mood, beliefs
Physiological effects
eg
Satiety, hunger, thirst, appetite
Attitudes
eg *to:*
Sensory properties, health/nutrition, price/value
Food Choice
Food Intake

Simplified representation of some of the factors influencing food choice and intake, along with interrelationships between them.



Studies on the effects of consuming various "preloads" (in this case four types of yoghurt) on subsequent motivation to eat showed that calories had a significant effect. For example, high calorie preloads brought about a greater reduction in hunger than low calorie preloads. Recovery in desire to eat and hunger was greatest following sweet preloads, with saccharin producing the largest effect.

ATTITUDES AND FOOD CHOICE

Three types of factor influence food choice: properties of the food and the physiological effects it produces, sensory and psychological factors that the food elicits in the consumer, and economic and social factors (see diagram).

Food choice needs to be understood at the level of the individual, at the level of natural groupings and at the aggregate population level. A study commissioned by the EC, and carried out over the past two years at IFR has investigated consumer attitudes to fat. The aim was to determine whether attitudes and choice of food was related to age, sex and social class.

A preliminary study examined people's knowledge of food, contrasting those with some professional connection with nutrition against engineering undergraduates, who were well educated but without specialist

Sensory evaluation occupies the middle ground between physical and chemical properties of foods and consumer choice.

knowledge. Then a wider study, involving over 500 people investigated individuals' beliefs about, and their attitudes to, particular foods. Finally, knowledge, beliefs, and attitudes, were related to actual eating habits. People's beliefs about food, and their attitudes to it, correlated well with their self-reported behaviour. However, people's perceptions corresponded only roughly with modern nutritional concepts. Thus, people do tend to favour food that they feel is "healthy"; but tend to relate healthiness to what they perceive as high fibre or vitamin content, rather than, for example, to fat content. People also tend to relate certain qualities of food that may not be closely related; for example, they tend to feel that food that is conspicuously salty must also be fatty. Habit also plays a large part in framing people's intake. As regards specific attitudes to fat: females tended to regard fat in a more negative light than males; the higher social classes were more negative than the lower; and younger people more negative than older.

In the future, AFRC researchers would like to investigate whether people are more inclined to change their eating habits if food changes only incrementally - for example if presented with low-fat foods which resemble high-fat foods; or whether it is more efficacious to make radical shifts. It also seems clear that people can reduce their preferences for some flavours if they substantially decrease their consumption of them; for example for salt, or for sugar in tea. It is not clear whether the same applies to a taste for fat, and if so whether this could suggest strategies for people to wean themselves off high fat diets.

AFRC-funded work at the University of Leeds is examining the effects of sweeteners on appetite control. By comparing the effects of intense sweeteners such as aspartame and saccharin (which have low or zero calorific value) with those of high calorie sweeteners such as sucrose, it should be possible to distinguish the relative contributions of sweet taste and energy input on the subsequent subjective expression of appetite and also on actual consumption of food. The results could have important implications in our understanding of the role of intense sweeteners as aids to dietary control by helping to determine whether energy input or sweet taste is the prime determinant of satiation.

The Leeds studies include a systematic comparison of intense sweeteners which differ in their chemical structures and biological activity, as well as their comparison with high calorie sweeteners. Some studies have already shown, for example, possible post-ingestional actions of some intense sweeteners when administered in capsule form which by-passes the taste receptors.

At the present time the results of a series of experiments have demonstrated that both the sweetness value and calorie content of a food contribute to an effect on appetite. However, these effects are different. A sweet taste will tend to stimulate appetite by raising the level of subjective hunger, whereas calories suppress hunger and subsequent food intake. For example a bland food (such as plain yoghurt) sweetened with saccharin augments hunger and increases food intake one hour later. Yoghurt sweetened to the same level with glucose has the opposite effect due to the presence of extra calories. These types of experiments, carried out under strictly controlled laboratory conditions, have indicated that all intense sweeteners cannot be considered to exert identical effects upon appetite. For example, although saccharin and aspartame tend to promote appetite via stimulation of the sweet taste their physiological effects after ingestion are quite different.

The objectives of these studies are theoretical and practical. The results advance understanding of the physiological processes underlying the control of appetite, and also provide a methodology for evaluating the satiating power of foods. The experiments therefore have scientific and commercial applications together with implications for regulatory authorities.

The development of preferences for the sensory characteristics of foods during early life has been studied in AFRC-funded research at the University of Birmingham.

There is evidence that adults' liking for a set of particular sensory characteristics at specific strengths in familiar foods is very largely acquired by personal experience - that is, habits induce likings. Studies at Birmingham suggest that this process starts very early in life and induces increasingly precise preferences as experience grows. For example, infants become less and less likely to prefer a lightly salted to an unsalted baby cereal if they continue to be exclusively breast fed after four months. Presumably, from that age the infant is learning to like the low level of sodium in breast milk. The Birmingham work has shown, moreover, that 6-month infants who have begun to be exposed to salt-containing foods show a degree of preference for the lightly salted cereal which is directly related to the number of experiences of salted food in the week before preference testing. Thus, at six months, experience of salt induces a liking for it generally. By 12 months, however, such preferences have become more specific, and are confined to the foods that the infant is currently eating with salt.

The role of mood and emotion in food choice is being examined in new AFRC studies at IFR on the relationship between some physiological effects of food and food preference. The research is concerned with the mechanisms by which food constituents, such as caffeine and related compounds, amino acids and carbohydrates, can influence mood and behaviour. Also of interest are the biological mechanisms underlying the hedonic aspects of eating (enjoyment of food). The capacity of foods to modify mood may help to explain the existence of an association between food cravings and certain mood states. There is evidence indicating that this relationship is particularly strong in individuals suffering from, for example, seasonal affective disorder or pre-menstrual syndrome, and generally the effects of food and eating on mood may well be more important than has been recognised previously.

A common interest which links much of the ongoing and proposed work in food acceptability is the function and acceptance of dietary fats. Ongoing efforts have been directed towards developing an understanding of the role of fats in the perception of food texture and identification of individual factors associated with consumption of diets and selected food high in fat. This work will now be supplemented with additional investigations of sensory, behavioural, and preference measures. An evolving programme on fats will seek to further examine the sensory properties of fats in foods, including texture and flavour modification, the development of preferences for these properties, and the roles of sensory perceptions, attitudinal, social, and physiological measures, in dietary fat consumption.

Sensory perceptions of foods are one of the most important determinants of food choice. Major programmes are in place on the development of new methods for measuring and understanding human perception and hedonic responses to foods, both in carefully controlled sensory evaluation and in consumer trials. A key area of research is mathematical modelling of consumer acceptability from sensory responses. Progress is also being made in developing instrumental measurements that are more closely related to consumer perception of quality. For example, the mechanical properties of food composites are being studied in part by using modification of a theory originally developed to explain deformation patterns in polymers and rubbers. This work will be applied to studies examining the effect of food composition on flavour release and perception.

Public perceptions of food safety risks have been examined. Three categories of people were involved in a survey: farmers, housewives and scientists. They were asked to rank in order of importance: nutritional imbalance, agrochemical residues, natural toxicants, food additives, environmental contamination, and microbiological aspects of food safety (food poisoning). All of the groups assessed food poisoning as the most important. Age did not affect ranking. Consumers with scientific training were the least concerned about food additives, and recognised the potential risk of naturally-occurring biologically active compounds. All groups perceived a higher risk associated with environmental and agricultural residues - farmers did not down-rate the impact of residues compared with other groups. ■

DIET AND HEALTH

Growing epidemiological evidence links cardiovascular and other chronic human diseases with diet and lifestyle. Research is aimed at providing the scientific data on which to base advice about the dietary requirements for optimal health, and ways to reduce the prevalence of avoidable, diet-related disorders. In many cases, IFR's broad range of disciplines offers valuable opportunities to bring physical and chemical methods to bear upon biological problems.

The work has two main aspects: the first concerns dietary requirements

Sources of dietary fibre are being studied: shown above are oat fractions and oat products. Photo: courtesy Edme.

and the individual. This includes studies on nutrient bioavailability, the relationship between dietary intake and biochemical indices of nutritional status and the development of functional indices of status which relate dietary habits to physiological and psychological performance. The second area concerns interactive effects of dietary constituents and health, and includes, for example, studies on the role of complex carbohydrates and dietary fat in relation to human lipid metabolism and haemostatic factors, both of which have direct implications for cardiovascular disease.

This area of science requires close collaboration between scientists at IFR, clinicians and medical research workers. Joint programmes have been developed with the MRC Dunn Nutrition Unit and with gastroenterology, paediatric, geriatric and diabetology departments within hospitals and universities. In the field of micronutrient nutrition, such collaboration encompasses studies of iron nutrition and psychomotor development in infants, and the influence of controlled dietary intervention programmes on a range of biochemical and functional indices of status in selected groups of the population.

In relation to macronutrients and fibre, IFR is investigating the relationship between the physical and chemical structure of cell wall polysaccharides and resistant starch, and their biological effects in the alimentary tract. Studies on the effect of dietary fibre on the proliferation of intestinal epithelial cells have shown that both the physical properties of fibre in the small intestine, and the products of bacterial fermentation, are involved in stimulating growth of the intestinal mucosa.

Studies on new sources of dietary fibre, such as processed brans from rice and oats, have shown that such materials may provide palatable alternatives to wheat or legume products, and often have their own particular physiological characteristics. For example, oats are a source of viscous non-starch polysaccharides with physiological properties similar to legume isolates such as guar gum. Dose-response studies indicate that oat consumption may lower blood cholesterol in humans, and experiments are underway to assess the potential practical implications for dietary control of cholesterol levels in the community.

How the composition of diets affects the amount of energy that is made available to the body, both for activity and for deposition as fat is also being investigated. Recently it has been shown that fermentable carbohydrates entering the large intestine provide about 2 kcal/g on average from a mixed diet. This is only half the amount obtained from fully digested starches and sugars, but it is much higher than the figure of 0 kcal/g which has previously been assumed. Work is currently in progress to assess more accurately the energy contribution of resistant starches, oligosaccharides and poorly digested sugars.

Another component of the AFRC programme concerns the identification and quantification of naturally occurring compounds in plant foods that may exhibit beneficial or deleterious properties, and the determination of their significance in the human diet. This involves close collaboration both with plant biologists and clinical researchers in order to devise screening methods for plant breeders, to determine human exposure levels, and to develop analytical techniques in support of physiological and clinical studies.

To take one example, saponins - which occur commonly in legumes - are known to reduce plasma cholesterol levels in man. However, the potential benefit of such an effect could be outweighed if the mechanism of reduction involves potentially toxic mechanisms. Research has shown that saponins increase the permeability of intestinal mucosal tissues, which might allow potentially allergenic compounds to pass through. However, different saponins vary greatly in their effects. For example, soya saponins, which occur most commonly in the UK diet, are of low activity, whilst alfalfa saponins are particularly potent.

This is just one example of a wider set of issues concerning bio-active natural compounds in food and research will be increased - particularly in the biological and clinical aspects of this work. ■

THE UK COUNTRYSIDE

Limits are being imposed on agricultural output, and land is being used for new purposes or taken out of production altogether. This does not diminish the need for agricultural research. The outstanding and in many ways more subtle task is to devise systems of agriculture that provide what is needed in ways that are non-polluting, meet the needs of farmers to diversify and be compatible with conservation. Examples of how AFRC research fills this brief are described below.

REDUCING NITRATE LEACHING

Intensive arable farming, in which the crop requires high inputs of nitrogen and is harvested in one sweep, seems bound to be "leaky" to some extent: some nitrogen will be lost as gases to the air, and some by leaching. Continuing research at the AFRC Institute of Arable Crops Research at Rothamsted is showing that much can be done, although the issue is far from simple - e.g. leaching does not result simply from surplus fertiliser, as is commonly supposed.

Complementary studies are underway at the AFRC Institute of Grassland and Environmental Research at Aberystwyth and North Wyke, on the little-studied issue of leaching from mixed swards of grass and clover, and from grass with a comparable input of nitrogen. Both institutes employ a range of investigative techniques, from spiking with heavy isotopes of nitrogen, to various methods for sampling soil water.

That leaching does not result simply from high inputs of fertiliser N is clearly shown in IACR studies in which some wheat plots received 200 kg N per hectare, and others received none.

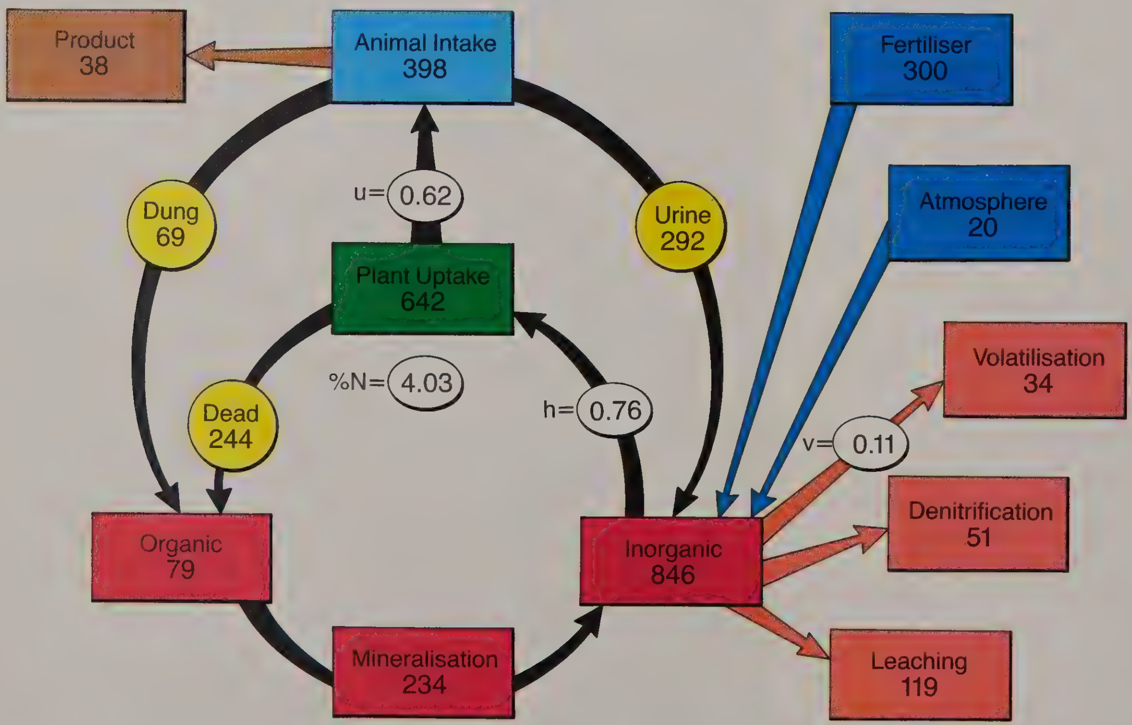
Phacelia, *one of the catch crops being investigated for its ability to mop up residual nitrogen in the soil. Others include forage rape and white mustard.*

At harvest, both left 52-55 kg N per ha as nitrate in the soil: no significant difference! Potatoes, however, give a very different picture. Plots given no fertiliser left 55 kg per ha of N as nitrate in the soil; while those with added N left around twice as much. The picture with sugar beet is closer to wheat, and rape is intermediate. The growth pattern of the crop seems largely to explain the differences. It seems that the N left after wheat is released from soil organic matter in late summer, when growth has ceased, and roots are beginning to die off. Potatoes, on the other hand, are harvested much later than wheat, and by then the late summer production of nitrate has proceeded further.

Research at the former AFRC Institute of Horticultural Research has shown that vegetables, such as onions and cabbage, can be particularly leaky. They have short growing seasons, and relatively feeble roots which scavenge poorly. But their growth in response to input of N does not plateau off as sharply as is the case with wheat; very heavy inputs do tend to produce bigger crops than moderate inputs, and because the crops are of high value, this extra input is economically worthwhile. The reasons for this phenomenon have been elucidated and a fertiliser injection technique devised that enables fertiliser levels to be greatly reduced without loss of yield.

The role of organic matter is equivocal. So long as the nitrogen remains in organic form, it cannot leach. But soil microbes continuously break down the organic material and release the N which can leach away. Ploughing of old grassland can thus lead to tremendous leaching.

In arable farming, there are two main ways to minimise leaching. The first is to ensure that the fields always contain growing crops. A possibility is to sow catch crops after harvest to mop up residual nitrogen. Rothamsted scientists are exploring several candidates; winter mustard, for example, can take up 90 to 100 kg N per ha, but since such catch crops are subsequently ploughed in, the timing and rate at which they release nitrogen is also important and is being investigated. The second approach is to gear the amount of N applied as precisely as possible to the needs of the plant. Computer models are being developed that should allow calculation of the amount of nitrate present in the soil at the time of applying nitrogen fertiliser, the amount that the crop should require; and hence the fertiliser requirement.



Layout of computer screen display simulating annual N fluxes for permanent grassland in S. England on a well drained loam receiving 300 kgN/hectare in fertiliser.

IACR scientists have been surprised to find that much of the arable land of Eastern and Southern England receives about 40 kg per ha of N each year from the atmosphere. A quarter to a third of this is in rain but the rest is in the form of oxides of nitrogen (from car exhausts and power stations), nitric acid vapour and ammonia (from farms). All future models of nitrogen leaching, and attempts to relate leaching to husbandry, must take account of this unseen input. They are particularly well advanced for the different vegetable crops and the models are being tested in nationwide fertiliser experiments both in this country and abroad.

Studies at IGER, Aberystwyth have compared leaching from lowland and upland sites, from clover-grass swards and from grass. The mixed swards received no added N; the grass plots received an amount equivalent to the calculated amount fixed by the clover in the mixed swards - about 150 kg per ha. In all cases, leaching was low and losses from the grass plots with fertiliser N were in most cases no greater than from the mixed sward, in which all the N came from N fixation. It seems that leaching becomes significant with inputs of 200kg per ha and above. Work continues to find ways of minimising leaching from grassland systems receiving relatively high inputs of nitrogen. A computer model of the nitrogen cycle of grassland has been developed to predict nitrogen losses according to fertiliser input, soil type, drainage, sward history and climate zone. It is based on average annual amounts of nitrogen in various components of the cycle in ten grazing experiments at the North Wyke and Hurley sites of IGER. This model indicates a wide variation in soil nitrogen mineralisation which greatly affects the proportion lost as nitrate. This must be taken into account in any legislative steps to reduce nitrate levels in drainage waters. ■

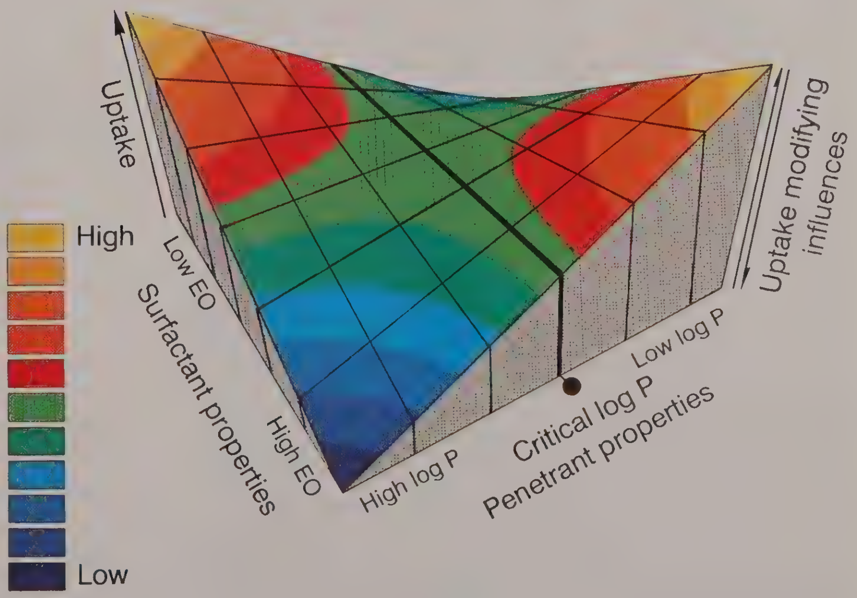
OPTIMISING THE EFFECTIVENESS OF AGROCHEMICALS

AFRC is researching several strategies to help increase the effectiveness of agrochemicals and eliminate wasteful applications. They include enhancing uptake in plants, timing spray application for the most suitable weather and soil conditions, and using the vascular tissues of plants to carry pesticides to their target.

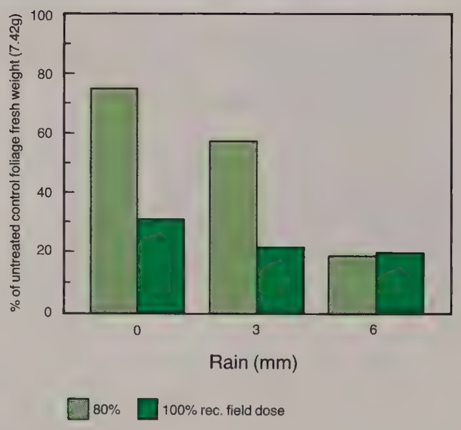
Surfactants enhance leaf penetration by many agrochemicals but their commercial use is often largely empirical. Studies at IACR Long Ashton, supported by Shell Research Limited, are elucidating the chemical basis of surfactant activity. One outcome should be a model for predicting which surfactants will work most efficiently with a particular pesticide. The work is showing that the conventional concept that surfactants act primarily by reducing surface tension of the spray liquid is erroneous; and also suggests that rational deployment of surfactants could increase the efficacy of some pesticides by up to 25 times.

Non-ionic surfactants with a low ethylene oxide content usually produce optimal uptake of compounds that have low solubility in water, while those with a high ethylene oxide content favour optimal uptake of compounds that are highly soluble in water. Uptake, however, is strongly influenced by the concentration of surfactant added, which can be critical. The degree of penetration depends on specific interactions between surfactant, active ingredient and target plant surface. Ultimately it should be possible to customise formulations, adjusting the surfactant to the pesticide and the crop. This research has also revealed examples of antagonism between surfactants and compounds which reduces uptake; this could help to keep surface-acting pesticides on the outside of leaves.

Amongst the most important classes of



A predictive model showing the effects of surfactant ethylene oxide content (EO) and water solubility (high log P = low solubility in water) on foliar uptake of agrochemicals.



Effect of applying simulated rain one week after application of the herbicide cyanazine to sterile brome. At the recommended field dose without rain foliage weight was reduced to 31% of that of the control, and both 3 and 6 mm of rain improved herbicide activity by about 10%. At 80% of the recommended field dose without rain foliage fresh weight was 75% of that of the control, and 3 and 6 mm of rain increased phytotoxicity by 15 and 55% respectively.

Sterile brome.

commercial herbicides are those that act by inhibiting a particular component of the photosynthetic machinery of plant cells - part of the Photosystem II reaction centre of green plants. AFRC-funded research at the University of Manchester Institute of Science and Technology is using molecular modelling techniques to identify the mechanisms by which herbicides bind to the polypeptide in the reaction centre, and inhibit photosynthesis.

Initially, modelling is being conducted with the reaction centre of the bacterium *Rhodopseudomonas viridis*, the structure of which has been determined by German scientists using x-ray crystallography. Molecular graphics are being used to study the conformation of protein and herbicide at the binding site. The relationship between the structure of the photosystem protein and its herbicide binding properties is being investigated by looking at the effects of amino acid substitutions in the polypeptide, which are known to cause herbicide resistance and by the use of herbicide analogues. Together these approaches should aid the design of novel, efficient and environmentally safe herbicides.

The state of the soil and subsequent weather conditions critically affect herbicide uptake and plant response, and therefore the dose necessary for effective control. Research supported by the Home Grown Cereals Authority at IACR, Long Ashton is defining and ranking the principal factors involved in order to identify "weather windows" when herbicide activity is likely to be greatest.

Initial studies have involved six herbicides used against sterile brome, an increasingly serious weed of arable fields. The most important factors affecting herbicide performance proved to be soil moisture at the time of application, and subsequent rainfall. Some of the herbicide enters through the leaves and damages them, but transport out of the leaves via the phloem is minimal. To pervade and kill the plant, therefore, the herbicide must enter the roots and be transported in the xylem. If the soil is dry at the time of application, the herbicide tends to adsorb to it and less is available to the plant. In addition, adventitious roots, which grow from the base of the shoot just below the soil surface under moist conditions, fail to develop in dry soil, reducing herbicide uptake. Rain immediately after application increases root uptake and herbicide efficacy, but for optimum performance the soil should be moist at the time of application. The bigger the weed becomes, the harder it is to kill: herbicide uptake increases with root and leaf area, but so does the plant's ability to metabolise the herbicide, and to develop new tillers and survive the treatment. Thus herbicide application at an early growth stage facilitates control.

Unlike many herbicides which can be transported in the vascular system of plants from leaves to roots, most insecticides and fungicides do not have the right physico-chemical properties for such phloem transport. However, suitably modified compounds might enable this route to be utilised to control root pests and diseases with foliar sprays of pesticides. Fundamental studies at IACR Rothamsted, in collaboration with ICI, are identifying the properties required by pesticides to move in phloem. Using the castor bean *(Ricinus communis)* system, the chemicals that are translocated best are weak acids that are slightly fat soluble (e.g. many plant hormones); chemicals that are not acidic, or that are too lipophobic or too lipophilic, are little transported in phloem. Although it will be difficult to alter the acidity and lipophilicity of existing pesticides without destroying their biological activity, chemists might also explore agents that they would hitherto have rejected, e.g. those with modest pesticidal activity but with properties conducive to phloem transport. ■

STRAW IS NOT FOR BURNING

Straw burning is scheduled to be outlawed after Autumn 1992. Research has already commenced on alternative methods of disposal including straw storage and processing for industrial use (see page 63). More immediately, farmers are likely to turn to systems for ploughing-in surplus straw. Research on straw incorporation and its consequences is conducted at the AFRC Institutes of Engineering Research and Arable Crops Research.

Straw must be chopped before incorporation. Studies have shown that this is readily achieved with a chopper on the back of the combine. Chop length is not critical; a median of around 5 cm is good enough, after which tine or disc cultivation is sufficient. Stripped straw (from a stripper combine harvester) decomposes at a similar rate to that of chopped material. Improvements have been made in a pre-production prototype of the Mixaplough which is designed to mix and bury crop residues, which have improved performance on wet cohesive soils and better soil flow characteristics. Good mixing of soil and straw is important in ensuring that compounds from the straw, such as acetic acid, do not impair germination of a subsequent cereal crop, as has been reported in the past.

Research suggests that straw incorporation need pose no inherent disease problems: septoria, rhynchosporia, and net blotch, carried over on trash, are not increased so much that they cannot be controlled by fungicide. Burning kills up to 70 per cent of weed seeds, particularly blackgrass and brome, and also tends to synchronise germination, which makes the weeds more amenable to herbicide attack. Brome control without burning will require astute management.

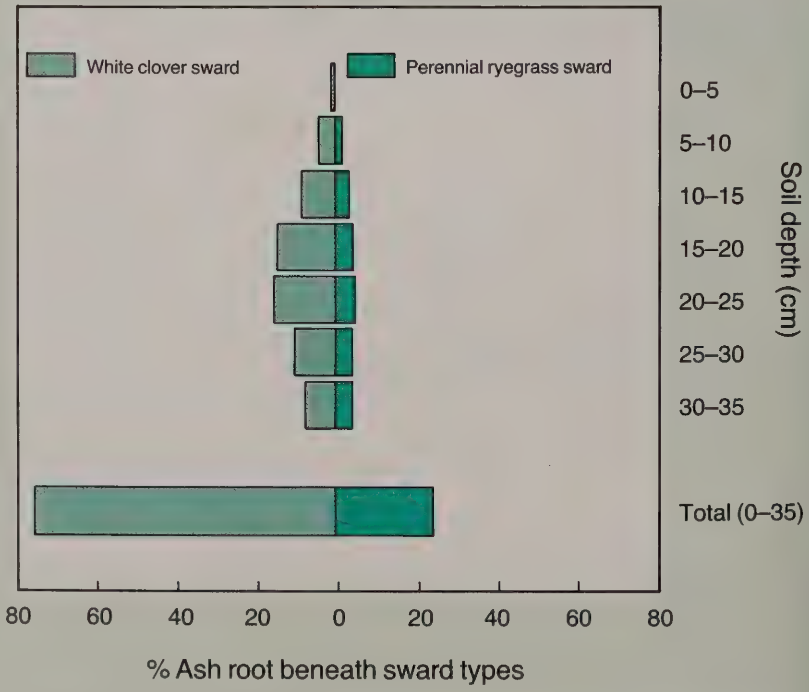
Straw is rich in organic carbon but deficient in nitrogen; so as soil bacteria attack the straw, they take up nitrogen from the soil. Incorporation could thus reduce leaching in winter, though it could theoretically increase N requirements the following summer. Long-term observation is needed to assess the influence of straw on nitrogen cycling, for it takes about 15 years for the first year's straw to disappear completely, and to establish a new equilibrium. ■

AGROFORESTRY

Agroforestry - the combination of agricultural and tree production on the same land offers enormous promise as an alternative land use system for the UK. It is already widely practised in other countries such as Australia, New Zealand and Africa. The AFRC is participating in a multi-site silvopastoral study (combined sheep and tree production) with the DAFS-funded Macaulay Land Use Research Institute, the Forestry Commission, and universities at Bangor and Belfast. This long term study will provide information on the effect of tree species and spacing on animal production. At IGER, Aberystwyth, research focuses on important belowground interactions between trees and sward.

To examine the effect of the sward on tree root growth, trees have been planted between contrasting sward types. Ash, for example, produced two to three times more root under a clover sward than under a ryegrass one. Current investigations are concerned with determining the factors influencing tree root growth under these circumstances, with a view to making recommendations regarding tree-sward compatibility.

Mycorrhizas could have an enormous influence on the partitioning of P between the sward and the tree. Mycorrhizal hyphae act as an extension of the root system and can scavenge efficiently for P which is then utilised by the host plant. Mycorrhizas can be divided into two morphological types: ectomycorrhizas (ECM) which are mainly found on trees and other woody species, and vesicular arbuscular mycorrhizas (VAM) which are mainly found on herbaceous species but also on some trees. It has been shown that individual plants (of the same or different species) can be physically united by mycorrhizal hyphal connections if both plants have the same type of mycorrhiza. Such links



Root growth under different sward types.

could provide routes for the exchange of nutrients. This effect has been demonstrated using VAM ryegrass labelled with radiophosphorus (^{32}P). The tops were removed so that the roots died: whereupon VAM trees (ash and sycamore) grown with the grass picked up much of the ^{32}P, although ECM hybrid larch did not. However, if ^{32}P was added directly to the soil, it was the larch that took the lion's share. Only when the ^{32}P came from the dying ryegrass roots could direct links play a role in the appearance of label in the VAM trees.

The science of tree improvement for farms and lowlands

For woodlands on farms and other fertile lowlands, the genetic and silvicultural quality of the trees planted is especially important. The main species of interest are the high value hardwoods, such as ash, beech, oak, elm, chestnut, sycamore and cherry, which have never been subjected to genetic improvement.

Scientists at the IHR at East Malling, Littlehampton and Wellesbourne are now bringing modern techniques in the plant sciences to bear on the problem of tailoring these trees for intensive planting. The model species adopted for this work are the wild cherry *(Prunus avium)*, and rose, which has an exceptionally short generation time and a small genome.

The major impediment in tree breeding is the long "juvenile" period, often of many years, before the trees flower, and during which selection of superior traits, such as timber quality, has not been possible. Cloning of outstanding individuals is the obvious alternative, as is already commonplace with the fast growing willows and poplars, as well as with fruit trees.

But in the slower growing, high value hardwoods, cloning by cuttings (which is the standard method) or micropropagation is possible only when the tree is immature or "juvenile". To be cloned superior trees will need to be identified when they are juvenile, or cloned when they are mature. There is also some advantage in the effect juvenility has on valuable characters, such as ease of rooting, wood quality, vigour and branching, since the difference in expression during the two phases of development provides a route to the genes controlling them. These genes can then provide the basis for genetic "finger-printing" to identify superior trees in the juvenile phase, and for direct genetic manipulation by transformation.

Accordingly, one major aim of the horticultural research programme is to understand the mechanisms and identify the genes that underlie the differences between juvenile and mature trees, and to seek ways of solving the "juvenility" problem. Hormone studies of *Prunus avium* have already shown, for example, that juveniles respond differently to specific gibberellins than mature trees. Gene libraries produced from juvenile or mature messenger RNA's from *Prunus avium* are being used to identify and clone genes specifically expressed during the two stages of development. Protein "markers" of the juvenile phase have also been discovered, and will be used for gene isolation. Genetic studies of isoenzyme and RFLP markers in *Prunus avium* have been started. Studies are also underway to develop the transformation (already achieved at East Malling for apple) and the other tissue culture technologies required, such as improved micropropagation. Hardwood species already micropropagated by the IHR include, oak, ash, cherry, birch, lime, plane, and sycamore.

Micropropagation is especially promising, because it has been found at East Malling to "rejuvenate" rooting and vigour. Work is underway to improve the micropropagation of mature trees, at present very difficult, and to understand how "rejuvenation" works. Other elements in the programme include work on desiccation tolerance in recalcitrant tree seeds and on the physiology of selection for stress tolerance at the nursery stage. Some of this work is carried out in collaboration with INRA, France.

Willows for energy

Willows have many traditional uses but they also have a potential as a non-food, renewable energy crop. Close planting and short rotation cropping produces maximum biomass in the shortest time. Typically, the first harvest can be taken after five years, and then repeatedly for another 20 to 25 years. Twelve tonnes of dry matter per ha per year is a reasonable yield, and Long Ashton has had yearly dry matter yields in excess of 18 tonnes per ha. This compares favourably with yields that conifers achieve only after 40 years. Willows should be a low-labour enterprise, and if prices are suitably but realistically adjusted, such output could produce an 11 per cent return on investment, and after the first five years (which are covered by set-aside grants) gross margins per ha should be comparable with those from cereals.

Early years of cultivation are more akin to horticulture than to agriculture. Weeds must be controlled as in the early years of their growth they cannot stand weed competition. Fungal diseases and pests are potentially serious problems in monocultures. Rust is already serious but Long Ashton is studying its epidemiology and the solution may be to establish plantings of mixed varieties or clones on which the impact of disease is reduced. The use of willows as biomass for fuel is receiving increasing interest at IACR, Long Ashton - the home of the National Willow Collection of around 600 lines. The work is in collaboration with the University of Aberdeen, the Department of Energy, and the Forestry Commission. ■

Willows are easy to propagate and establish from cuttings. As well as growing on surplus cereal land, willows have the added attraction of being able to grow on land that is often too wet for most crops.

NEW LIVESTOCK OPTIONS

Deer are already an established alternative to sheep for some areas of Britain, a better understanding of their physiological responses to daylength is essential for their efficient management. Camelids offer interesting options for fine wool production, but much of their basic biology has hardly been described. Research is helping to provide the information necessary if farmers are to make better use of these options.

Wool production from South American camelids - alpacas, guanacos and llamas - is already exciting interest as an alternative enterprise among livestock farmers in less favoured areas. Projects at IGER, Aberystwyth, supported by an open contract from MAFF, are exploring the basic nutrition of guanacos and alpacas, for example, to identify the optimum feeding for maximum wool growth and reproduction, and to explore the possibilities for feeding on natural upland pastures, and for mixed stocking with sheep and goats. In close association, the Institute of Zoology in London is exploring camelid reproduction; and in particular, the possibilities for artificial insemination and embryo transfer, to encourage multiplication of favoured animals and the importation of new genes from South America. In this work, IGER is collaborating with the Institute of Zoology, Regents Park; and the University of Santiago, Chile. Complementary programmes are also underway at two DAFS-funded institutes: the Rowett Research Institute and Macaulay Land Use Research Institute.

Deer are highly seasonal breeders, and give birth naturally in May to June - too late to make best use of spring grazing, and giving the calf little time to put on weight before winter. Calving can be brought forward by treatment with melatonin - but the animals are seasonal also in coat growth and nutrition, and if reproduction is brought forward in this way, then the hinds also lose appetite in late winter, and so enter the winter period at lower weight than is desirable. Research at MLURI, in collaboration with the Institute of Zoology in London, aims first to understand the basis of this seasonality, and to manipulate it so that hinds that breed early do not subsequently lose their appetite. The ultimate aim is to control these cycles not by administering hormones, but by genetic means.

The MLURI scientists have compared the intake of hinds that had been given melatonin or not given melatonin, and were lactating or not lactating, when food was easy to come by (tall herbage and high dry matter per unit area), or not easy to come by (low herbage). When food was readily available, the animals that had been given melatonin ate significantly less than the control animals when food was readily available. But when food was less available, the control animals also ate little: that is, they did not put in the extra effort needed, as they could have done, to obtain more food. It has been argued that the innate decline in appetite in autumn is an adaptation to the onset of winter; the animals do not waste time seeking food that is not there. However, it seems that deer reduce their appetite in line with food availability even when they are not hormonally primed to anticipate winter. But lactating animals, which clearly need a greater energy intake, were prepared to spend more time grazing. In addition, the lactating animals sought out richer grazing - more grass, less heather - than the non-lactating animals did.

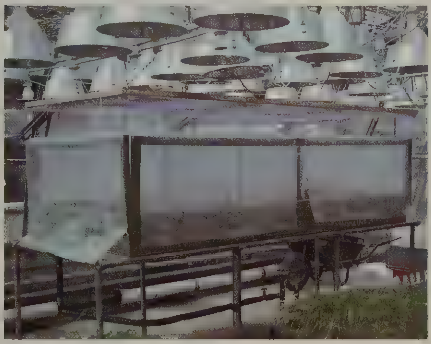
These experiments show that appetite is controlled by factors such as lactation, superimposed on a seasonal cycle which can be modified by treatment with melatonin. But if food is difficult to come by - that is, if the sward is too short - then this too overrides the innate appetite cycle. ■

Studies on the basic nutrition and physiology of camelids such as these guanacos will lay the foundations for practical husbandry systems.

VETCH SAVED FROM ONCOMING TRAFFIC

Britain's finest remaining colony of the wood bitter vetch, *Vicia orobus*, was in danger when the SSSI where it has been growing in Wales was threatened by the widening of the A470. It was saved by scientists at IGER, Aberystwyth, using techniques developed to establish seed banks.

Wood bitter vetch used to be grown for forage, but is now rare, and is virtually confined to the west of Britain. Although it survives in Europe, the British strains are distinct. Attempts to conserve the plant by transplantation were unsuccessful; and the main hope lay in the seeds. It seemed desirable, and indeed essential, for the long-term viability of the colony after it had been replanted, to preserve as much of the genetic variation as possible. To study the range of genetic variation, IGER scientists explored various isoenzymes (molecular variations of the same enzyme) of the plants; but in fact found very little diversity among them. The more general task, was simply to preserve seed from as many plants as possible. Many had suffered insect damage, but even these were conserved - by "embryo rescue"; separating the embryos (which are usually intact) from the damaged endosperms, and growing them up on culture. This technique has virtually 100 per cent success rate. The plants have now been returned to the completed roadside bank, and in their second season seem to be doing well. ■



Wood bitter vetch seedlings, derived from "embryo rescue", growing under mist propagation.

RESEARCH PARTNERSHIPS IN EUROPE

AFRC has continued to build upon its collaborative research links with other European centres of excellence, both within the EC and the EFTA, through expanding its bilateral agreements and by increased participation in the EC R&D Framework Programme.

We have strengthened our close research links with the French Institut National de la Recherche Agronomique (INRA). The first annual review of co-operation took place in December 1989 with meetings to evaluate progress in plant science, animal science and food science; and priority themes for each area were confirmed for 1990. We are developing a joint AFRC/INRA fellowship scheme.

A Memorandum of Understanding between the AFRC Institute of Engineering Research and the French Centre National du Machinisme Agricole du Génie Rural, des Eaux et des Forêts (CEMAGREF) was signed in 1989. IER and CEMAGREF have collaborated closely in the establishment and development of the European Community Club of Advanced Engineering in Agriculture. This aims to promote the important technical and economic contribution which engineering and the physical sciences can make to agriculture and associated industries within the EC.

AFRC has placed high priority on the development of further bilateral agreements with The Netherlands, The Federal Republic of Germany and Spain. Preliminary visits have taken place and progress is being made in identifying priority areas for future collaboration. An example is the establishment of links between the AFRC Institute for Animal Health and leading laboratories in Spain in the fields of foot-and-mouth disease virus and African swine fever.

AFRC scientists have successfully bid for research contracts within the FLAIR (food research), ECLAIR (agro-industrial research) and BAP (biotechnology) programmes. In 1989-90 AFRC received a total of £1.4M from EC sources, an increase of 44% from the previous year.

Proposals have been made for substantial AFRC participation in the 1990-1993 biotechnology programme (BRIDGE). These include projects on mapping the pig genome, developing vectors for gene transfer in animals, the use of recombinant technology to produce novel vaccines for animal health, isolation and characterisation of lactic acid bacterial proteases important in flavour development, and plant biology programmes on the genetic control of flowering, metabolic pathways in higher plants, and the molecular mechanisms by which viruses move from one cell to another.

The Pirbright Laboratory of the AFRC Institute for Animal Health has been designated the European Reference Laboratory for Foot-and-Mouth Disease (FMD), with effect from April 1990. Additional funding from the EC is being provided, and the Laboratory will take specific responsibility for providing a diagnostic service for FMD to the EC; providing standardised reagents to FMD laboratories in the EC; and for providing training to staff of other EC laboratories.

With our partners in the EC we are looking to strengthen collaboration with researchers in other developed countries, and in particular to foster stronger links with the National Science Foundation in the USA. Already promising co-operation is planned on the molecular biology of *Arabidopsis.*

AFRC scientists already collaborate with researchers in East European countries and we are exploring the newly emerging opportunities to build up existing links, for example, within programmes of the British Council and other organisations.

Some examples of AFRC collaborative research in Europe are given on the following pages. They include a project between the AFRC Institute of Arable Crops Research, the University of Nottingham and INRA on remote sensing of crops; protein engineering studies on new phospholipases at the AFRC Institute of Food Research in collaboration with university groups in The Netherlands; basic studies on lactic acid bacteria that are leading to their controlled manipulation to increase their industrial usefulness - a project within the Biotechnology Action Programme involving researchers in four European countries; development of a European database of forage plants at the AFRC Institute of Grassland and Environmental Research; and projects with East European partners on the genetics of bread wheat, combined techniques to control growth of food poisoning bacteria, and grain drying.

SSOCIATIONS UROPEENNES POUR LA ECHERCHE

'AFRC continue à établir des liens avec d'au- es centres européens de recherche de premier dre au sein de la CEE et de l'EFTA par la nature d'accords bilatéraux et par une par- ipation accrue au Programme Cadre de la cherche et du Développement de la CEE.

ous avons renforcé nos liens scientifiques avec nstitut National Français de Recherche Agro- mique (INRA). La première revue annuelle coopération a eu lieu en décembre 1989 avec s réunions permettant d'évaluer les progrès ns le domaine des sciences végétales, ani- les et nutritionnelles; des thèmes prioritaires ur chacun de ces sujets ont été choisis pour 90. Nous avons dès 1990 lancés des bourses RC/INRA.

Accord (Memorandum of Understanding) a été signé entre l'Institut de Recherche en Génie Agricole de l'AFRC et le Centre National Français du Machinisme Agricole du Génie Rural, des Eaux et des Forêts (CEMAGREF) en 1989. L'IER et le CEMAGREF ont collaboré de très près à l'établissement et à l'élaboration du Club Européen des Techniques Avancées appliquées au Génie Agricole. Il a pour but de promouvoir au sein de la CEE la contribution technique et économique du Génie et des sciences physiques dans le domaine de l'agriculture et des industries qui en découlent.

L'AFRC a donné priorité au développement d'accords bilatéraux futurs avec les Pays-Bas, l'Allemagne et l'Espagne. Des visites préliminaires et des progrès notables ont eu lieu dans le cadre de l'identification des sujets prioritaires qui feront l'objet d'une collaboration future. Par exemple, des liens ont été établis entre l'Institut pour la Santé Animale (de l'AFRC) et les principaux laboratoires espagnols dans le domaine des virus entraînant la fièvre aphteuse, et la fièvre africaine des porcs.

Les scientifiques de l'AFRC ont réussi à conclure des contrats de recherche dans le cadre des programmes suivants: FLAIR (recherche alimentaire), ECLAIR (recherche agro-industrielle) et BAP (biotechnologie). En 1989-1990, l'AFRC a reçu un total de 1,4 million en livre sterling de différentes sources européennes, soit une augmentation de 44% par rapport à l'année précédente.

Des propositions ont été faites pour renforcer considérablement la participation de l'AFRC au programme de biotechnologie (BRIDGE) pendant la période 1990-1993. Ces propositions comprennent des projets pour identifier le génome du porc, développer des vecteurs concernant le transfert des gènes dans les animaux, utiliser la technologie de recombinaison afin de produire de nouveaux vaccins pour la santé animale, isoler et caractériser les protéases bactérielles de l'acide lactique si importantes pour le goût. Et enfin, ces propositions contiennent des programmes de biologie végétale sur le contrôle génétique de la fleuraison, les différentes routes métaboliques des plantes supérieures et les mécanismes moléculaires permettant aux virus de se transmettre d'une cellule à une autre.

Le Laboratoire de Pirbright, faisant partie de l'Institut AFRC pour la santé animale, a été désigné Laboratoire Européen de Référence pour la fièvre aphteuse, il est fonctionnel depuis avril 1990. La CEE a avancé des fonds supplémentaires et le Laboratoire prendra la responsabilité spécifique de procurer à la CEE un service de diagnostiques sur la fièvre aphteuse, en fournissant des réactifs normalisés aux laboratoires européens qui traitent la fièvre aphteuse, et aura la responsabilité de fournir une formation au personnel des autres laboratoires de la CEE.

Avec nos partenaires européens,nous cherchons à renforcer la collaboration avec les chercheurs des autres pays développés, et plus particulièrement avec la Fondation Nationale des Sciences aux USA. Nous avons déjà établi une coopération prometteuse qui traite de la biologie moléculaire d'Arabidopsis.

Les scientifiques de l'AFRC ont déjà entrepris plusieurs collaborations avec les chercheurs des pays de l'Est de l'Europe et nous étudions les nouvelles possibilités qui se présentent afin de nouer des liens plus profonds, par exemple, au sein de programmes appartenant au British Council ou à d'autres organisations.

Quelques exemples de la recherche collaborative du AFRC en Europe sont présentés dans les pages suivantes. Ils contiennent: un projet d'études entre l'Institut de Recherche AFRC sur les Produits Agricoles , l'Université de Nottingham et l'INRA sur l'analyse automatique des récoltes; des études de manipulation de protéines sur de nouveaux phospholipases à l'Institut AFRC de Recherche Alimentaire en collaboration avec des groupes universitaires aux Pays-bas; des études de base concernant les bactéries d'acide lactique qui entraînent un contrôle des manipulations afin de faciliter leur application industrielle, ce projet fait partie du programme d'Action de Biotechnologie et il est suivi par quatre pays européens différents. D'autres exemples sont présentés tels que: le développement d'une base de données européennes pour les plantes de fourrage à l'Institut AFRC de Recherche sur les Herbages et l'Environnement, et un certain nombre de projets avec des partenaires européens de l'Est portant sur la génétique du froment, sur la combinaison de techniques permettant de contrôler la croissance des bactéries qui entraînent les empoisonnements et sur les techniques de séchage du grain.

RSCHUNGSPARTNER- HAFTEN IN EUROPA

er AFRC hat weiterhin auf seine kollabora- ven Forschungsverbindungen mit anderen ropäischen Stätten hervorragender Qualität der EG als auch in der EFTA aufgebaut, nd zwar durch Ausdehnung seiner bilatera- en Vereinbarungen und durch erhöhte eteiligung am Forschungs- und Entwicklungs-Rahmenprogramm der EG.

Wir haben unsere engen Forschungsverbindungen mit dem Institut National de la Recherche Agronomique (INRA) (Nationalinstitut für Landwirtschaftsforschung) in Frankreich verstärkt. Die erste jährliche Überprüfung der Kooperation fand im Dezember 1989 mit Treffen statt, um den Fortschritt in der Pflanzenwissenschaft, Tierwissenschaft und Ernährungswissenschaft auszuwerten; und es wurden Prioritätsthemen für jedes Gebiet für 1990 bestätigt. Wir sind dabei, einen gemeinsamen AFRC/INRA-Stipendiumsplan zu entwickeln.

1989 wurde ein Memorandum des Verständnisses zwischen dem AFRC Institute of Engineering Research und dem französischen Centre National du Machinisme Agricole du Genie Rural, des Eaux et des Forets (CEMAGREF) unterschrieben. IER und CEMAGREF haben bei der Gründung und Entwicklung des EG Club für Fortgeschrittene Technik in der Landwirtschaft eng zusammengearbeitet. Sein Ziel ist, den wichtigen technischen und wirtschaftlichen Beitrag zu fördern, den die Technik und die physikalische Wissenschaft für die Landwirtschaft und die damit verbundenen Industrien innerhalb der EG machen kann.

Der AFRC hat der Entwicklung weiterer bilateraler Vereinbarungen mit den Niederlanden, der Bundesrepublik Deutschland und Spanien hohe Priorität gegeben. Einleitende Besuche haben bereits stattgefunden und es sind Fortschritte erzielt worden bei der Identifizierung von Prioritätsgebieten für eine zukünftige Zusammenarbeit. Ein Beispiel dessen ist die Herstellung von Verbindungen zwischen dem AFRC Institute for Animal Health (Institut für Tiergesundheit) und führenden Labors in Spanien auf den Gebieten der Viren von Maul-und-Klauen-Seuche und von afrikanischer Schweinepest.

Wissenschaftler des AFRC haben erfolgreiche Angebote für Forschungsverträge innerhalb FLAIR (Nahrungsmittelforschung) und ECLAIR (landwirtschaftliche-industrielle Forschung) und BAP-Programmen (Biotechnik) gemacht. 1989-90 erhielt AFRC eine Gesamtsumme von £1.4 Mio von EG-Quellen, ein Anstieg von 44% zum Vorjahr.

Es wurden Vorschläge für eine erhebliche AFRC-Beteiligung beim biotechnischen Programm (BRIDGE) gemacht. Dieses umfaßt Projekte über die Aufzeichnung des Schweinegenbestands, entwickelnde Vektoren für die Genübertragung bei Tieren und die Anwendung von Rekombinationstechnik, um neuartige Impfstoffe für Tiergesundheit, Isolierung und Charakterisierung der bakteriellen Proteasen der Milchsäure, die wichtig für die Geschmackentwicklung sind, herzustellen sowie Pflanzenbiologie- Programme über die genetische Kontrolle von blühenden, metabolischen Wegen in höheren Pflanzen und der molekulare Mechanismus, durch den Viren sich von einer Zelle zur nächsten fortbewegen.

Das Labor des AFRC Institute for Animal Health in Pirbright wurde mit Wirkung ab April 1990 als das europäische Bezugslabor für Foot-and-Mouth Disease (FMD) (Maul-und-Klauenseuche) bestimmt. Zusätzliche Finanzierung erfolgt seitens der EG und das Labor hat die spezielle Verantwortung, der EG einen diagnostischen Dienst für die Maul-und-Klauenseuche zu geben, standardisierte Reagenzien an die FMD-Labors in der EG zu liefern und Schulung für Angestellte anderer EG-Labors zu stellen.

Mit unseren Partnern in der EG planen wir, die Zusammenarbeit mit Forschern in anderen entwickelten Ländern zu stärken und insbesondere stärkere Verbindungen mit der National Science Foundation in den USA zu fördern. Eine versprechende Kooperation über molekulare Biologie der Arabidopsis ist bereits geplant.

Wissenschaftler des AFRC arbeiten bereits mit Forschern in osteuropäischen Ländern zusammen und wir untersuchen augenblicklich die neu entstehenden Gelegenheiten, um bestehende Verbindungen auszubauen, zum Beispiel innerhalb der Programme des British Council und anderer Organisationen.

Einige Beispiele der kollaborativen Forschung des AFRC in Europa werden auf den folgenden Seiten gegeben. Sie umfassen ein Projekt zwischen dem AFRC Institute of Arable Crops Research, der Universität von Nottingham und INRA über Fernabtastung von Feldfrüchten; Studien über Proteintechnik bezüglich neuer Phospholipasen am AFRC Institute of Food Research (Institut für Nahrungsmittelforschung) in Zusammenarbeit mit Universitätsgruppen in den Niederlanden; Grundstudien über Milchsäurebakterien, die zu ihrer kontrollierten Manipulation führen, um ihre industrielle Anwendungsfähigkeit zu steigern – ein Projekt innerhalb des Biotechnologischen Aktionsprogramms, in dem Forscher in vier europäischen Ländern verwickelt sind; Entwicklung einer europäischen Datenbank über Futterpflanzen am AFRC Institute of Grassland and Environmental Research (Insitut für Graslandschaft und Umweltforschung); sowie Projekte mit osteuropäischen Partnern über die Genetik von Brotweizen, kombinierte Techniken, um das Wachstum von Bakterien, die Nahrungsmittelvergiftung hervorrufen, zu kontrollieren sowie das Trocknen von Getreide.

COLABORACION EN LA INVESTIGACION EN EUROPA

El AFRC ha seguido desarrollando sus vínculos con otros centros de excelencia europeos en cuanto a colaboración en la investigación, tanto dentro de las Comunidades Europeas, como de la AELC, a través de la expansión de su acuerdos bilaterales y una mayor participación en el Programa de Estructuración de la Investigación y Desarrollo de las Comunidades Europeas.

Hemos reforzado nuestros cercano vínculo con el Institut National de la Recherche Agronomique (INRA) en Francia. La primera retrospectiva anual de la cooperación tuvo lugar en diciembre de 1989 durante reuniones para evaluar el avance relativo a la ciencia de las plantas, ciencia de los animales, y ciencia de los alimentos, y se confirmaron temas prioritarios en cada sector para 1990. Estamos desarrollando un programa de asociación conjunta del AFRC/INRA.

En 1989 se firmó un Memorándum de Entendimiento entre el Institute of Engineering Research del AFRC y el Centre National du Machinisme Agricole du Génie Rural, des Eaux et des Forêts (CEMAGREFF) de Francia. El IER y el CEMAGREFF han trabajado en estrecha colaboración para establecer y desarrollar el European Community Club of Advanced Engineering in Agriculture, cuyo objetivo es el de promover la importante contribución técnica y económica que la ingeniería y las ciencias vinculadas con la física pueden aportar a la agricultura e industrias relacionadas dentro de las Comunidades Europeas.

El AFRC ha concedido una elevada prioridad al desarrollo de una mayor cantidad de acuerdos bilaterales con los Países Bajos, Alemania Federal y España. Se han producido visitas preliminares, y se están efectuando avances en cuanto a la identificación de áreas prioritarias para la futura colaboración. Un ejemplo está dado por el establecimiento de vínculos entre el Institute for Animal Health del AFRC y los principales laboratorios españoles dentro del campo del virus de la fiebre aftosa y la fiebre porcina africana.

Los científicos del AFRC han obtenido éxito en la licitación para contratos de investigación dentro de los programas FLAIR (investigación alimentaria), ECLAIR (investigación agroindustrial) y BAP (biotecnología). En 1989/90 AFRC recibió un total de 1,4 millones de libras esterlinas de fuentes de las comunidades europeas, un incremento del 44% respecto del año anterior.

Se han efectuado propuestas para una importante participación del AFRC en el programa de biotecnología (BRIDGE) 1990-1993. Tales propuestas incluyen proyectos para el diagramado del genoma porcino, el desarrollo de vectores para la transferencia de genes en los animales, el uso de tecnología de recombinante para producir nuevas vacunas para la salud animal, aislamiento y caracterización de proteasas bacterianas de ácido láctico, y programas de biología de las plantas en relación con el control genético de la floración, los cursos metabólicos en las plantas superiores, y los mecanismos moleculares por los cuales los virus se trasladan de una célula a otra.

El Pirbright Laboratory del Institute for Animal Health del AFRC ha sido designado como el Laboratorio de Referencia Europea para fiebre aftosa, con efecto a partir de abril de 1990. Las Comunidades Europeas están otorgando una subvención adicional, y la específica responsabilidad del laboratorio será la de proporcionar un servicio de diagnóstico de fiebre aftosa dentro de las Comunidades Europeas; abastecer de reactivos estándar a los laboratorios para fiebre aftosa dentro de las Comunidades Europeas; y proveer para la formación de personal de otros laboratorios dentro de las Comunidades Europeas.

Junto con nuestros asociados dentro de las Comunidades Europeas estamos intentando incrementar la colaboración con investigadores dentro de otros países desarrollados, y en particular, promover vínculos más estrechos con la National Science Foundation en los EE.UU. Ya se tiene programada la colaboración en relación con la biología molecular de Arabidopsis.

Los científicos del AFRC ya colaboran con investigadores de países de Europa Oriental, y estamos estudiando las nuevas oportunidades para desarrollar los vínculos existentes, por ejemplo, dentro de los programas del British Council y demás organizaciones.

En las páginas que siguen brindamos algunos ejemplos de la investigación del AFRC en colaboración con otros cuerpos, los cuales incluyen un proyecto entre el Institute of Arable Crops Research del AFRC, la Universidad de Nottingham y el INRA sobre la apreciación remota de cultivos; estudios de ingeniería de proteínas acerca de las nuevas fosfolipasas en el Institute of Food Research del AFRC en colaboración con grupos universitarios de los Países Bajos; estudios básicos sobre las bacterias de ácido láctico que están llevando al control de su manipulación para incrementar su utilidad industrial, proyecto que se encuentra dentro del Biotechnology Action Programme y que incluye investigadores de cuatro países europeos; desarrollo de una base de datos europea acerca de plantas forrajeras en el Institute of Grassland and Environmental Research del AFRC; y proyectos con asociados en Europa Oriental sobre la genética del trigo para pan, técnicas combinadas para controlar el desarrollo de bacterias que producen intoxicación alimentaria, y el secado de granos.

LEGUMES: IMPROVING NUTRITIONAL STATUS AND QUALITY

A Pan-European initiative with commercial companies within the ECLAIR (European Collaborative Linkage Agro-Industrial Research) programme of the EC.

Leguminous seeds are second only to cereals as staple foods for humans and as concentrated feed for animals, but they still have tremendous untapped nutritional and agronomic potential. A programme has been established to increase the use of grain legume seeds by improving their quality and nutritional value by genetics and technological transformation. It involves some 20 laboratories in seven countries, including researchers at the John Innes Institute, the AFRC Institute of Food Research and Plymouth Polytechnic, together with twelve industrial partners. All the principal seed legumes of the Community will be investigated: faba bean, lupin, soya, chickpea, and the kidney bean group. Work will focus initially, however, on the pea, the genetics of which is best understood.

Leguminous seeds are high in protein (commonly about twice as high as cereals) and there is wide variation for starch, lipid and fibre. The chemical and genetic basis of different quality and functional properties in a range of varieties will be characterised, so as to identify strategies for improvement. One aim, for example, is to determine the influence of composition and structure on the behaviour of starch during gelatinisation.

Legumes have beneficial pharmacological effects, including a propensity for lowering blood cholesterol. The mechanism of this, and the genetics underlying the beneficial agents, need to be explored; again with the longer term aim of guiding crop improvement programmes.

On the debit side, legumes contain alkaloids, saponins, tannins, isoflavones, lectins, enzyme inhibitors, and oligosaccharides, which in general are antinutrients, and in some cases are toxic. Increasing interest in "health food" and in vegetarianism in Europe could increase consumption of these minor seed components 10 or 100 fold, so that many could be consumed in significant amounts. Some of these agents are known to protect the seeds from insect or pathogen attack, and to be essential for germination. The composition of different lines will be analysed and the underlying genetics investigated. ■

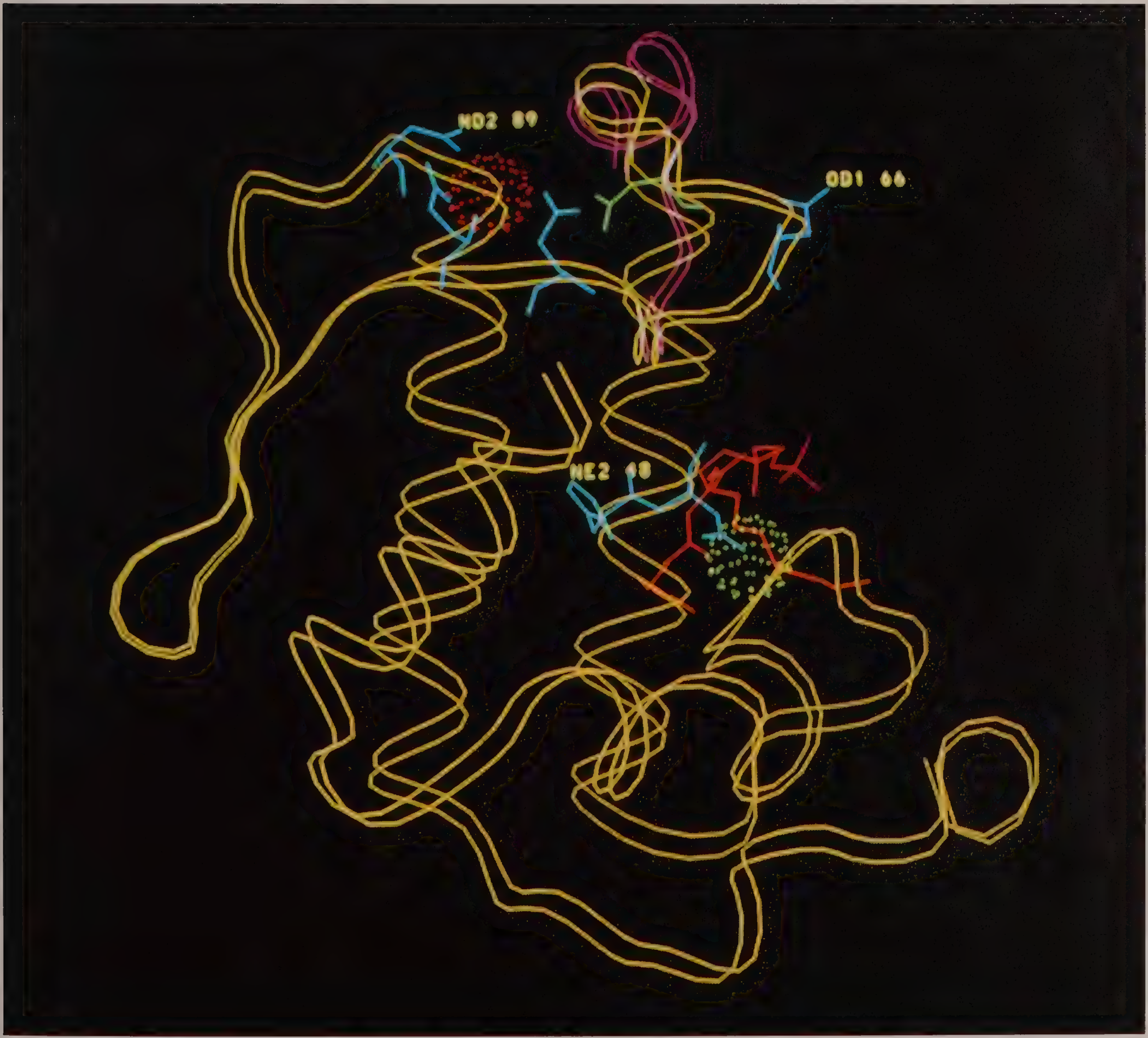
Legume seeds from all over the world, most of which contain saponins.

FAT SPLITTING ENZYMES BY DESIGN

A UK-Netherlands collaboration that could lead to novel ways to improve food fats.

One application of protein engineering is to alter the stability and specificity of enzymes so as to enhance their industrial usefulness. Fundamental research at the AFRC Institute of Food Research on the complex relationship between the 3-D structure of proteins and their biological activity includes studies on the enzyme phospholipase A_2. Phospholipases are used commercially in the preparation of food emulsifiers and pharmaceuticals. This research is conducted in collaboration with scientists at the universities of Utrecht and Groningen in The Netherlands. It has led to creation of mutant phospholipases with modified stabilities.

Enzyme stability depends on the difference in the energy required to maintain it in its folded and functional state, and the energy needed to sustain



Structure of porcine phospholipase A_2 showing active site histidine (48); phospholipid substrate (red); and primary calcium (green sphere). The secondary calcium site is also shown (red sphere). Aspartic acid 66 could be involved in binding the second calcium if the loop on which it is situated adopted the conformation seen in the bovine structure (pink loop, asp 66 (bovine) green).

it in a denatured, unfolded form. Working from knowledge of the three-dimensional structure as revealed by x-ray crystallography, IFR scientists have calculated the distribution of electric charge on the surface of the functional enzyme. They have also worked out what changes would be needed to increase or reduce the stability of the folded structure. From this, they have calculated the kinds of changes that could be made in the primary structure (the sequence of amino acids) to produce the required alterations in charge.

From these calculations, two mutant forms of phospholipase A_2 have been created. In one, the electrically neutral amino acid asparagine at position 89 has been replaced by negatively charged aspartic acid. In the other, aspartate also replaces asparagine at position 89; and at position 92, the negative glutamic acid is replaced by the positive lysine. Both mutants retained their enzyme activity. Theory predicted that the first would be slightly less stable than the native enzyme; and that the double mutant would be more stable. Exposure to denaturants showed that the double mutant was more stable as expected and the stability of the single mutant increased slightly. In addition the activity of the single mutant is enhanced.

The nature of phospholipase specificity - why it requires the phosphorus bearing group in order to bind to its substrate - is also being explored at IFR. One aim is to create new enzymes for use in fat interesterifications for upgrading of oils and fats such as palm oil and tallow. At present, only enzymes with specificities at the 1 and 3 positions of triglycerides are readily available. If a 2-specific lipase could be produced by engineering a much wider range of alternative, inexpensive sources of fat could be converted into fats with improved nutritional and functional properties. ■

LUPINS FOR NORTHERN EUROPE

A study in collaboration with French, German, Polish and Spanish scientists.

The EC currently imports 20 million tonnes of soya bean products annually for oil and as animal protein feedstock. Lupin can be considered as an alternative protein source as most varieties contain around 40 per cent of high quality protein in their seed, similar to soya bean, and much more than the 25 per cent in peas and beans. Through an intensive multidisciplinary programme, lupins have been successfully developed as a major protein crop in Australia. The EC now annually imports more than eight million tonnes of lupins from this source.

Lupins are widely grown in southern Europe but the total acreage and production is small. They have been extensively trialled in the UK but although they grow well in northern climates, currently available varieties mature late, often in late November, and are thus difficult to harvest and to fit properly into crop rotations. This is because their indeterminate flowering habit results in tall plants with up to five or six successive flushes of flowers throughout the growing season. In Mediterranean climates, growth is cur-

The effects of different durations of seed vernalisation on the pattern of flowering of white lupins (Lupinus albus). *From left to right; unvernalised control, and vernalised for 2, 4 and 6 weeks at 1°C.*

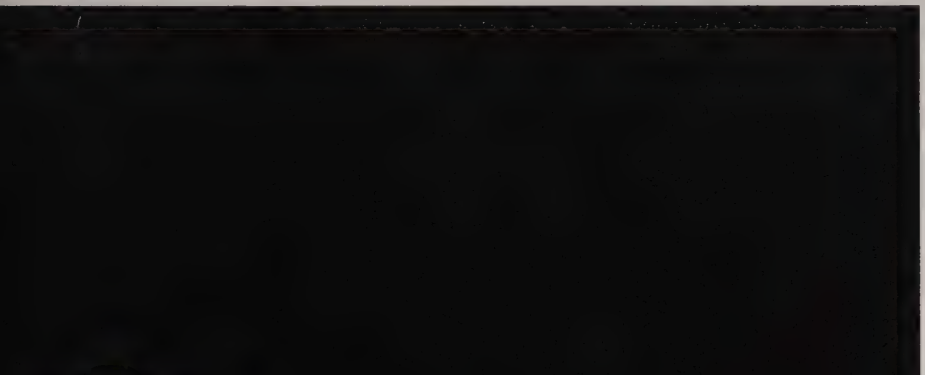
tailed and maturation induced by high temperatures and lack of water.

Scientists at the AFRC Institute of Arable Crops Research at Rothamsted are collaborating with groups in France, Federal Republic of Germany, Poland and Spain. The aim is to develop for northern Europe an ideally structured lupin that will combine earliness to maturity with adequate and stable yield. The approaches include physiological manipulation through seed vernalisation, manual pruning and the introduction of novel germplasm to produce plants of different structure and to test their performance under British conditions.

Physiological experiments have shown that if imbibed lupin seed are chilled at temperatures close to freezing for periods ranging from two to six weeks, plants grown from the seed flower earlier and are more determinate in their flowering. With the longest periods of seed vernalisation plants can be induced to be fully determinate and produce only a main-stem inflorescence and single florets in place of axillary branches. Shorter exposures produce intermediate types. Such plants mature up to a month earlier than indeterminate types.

Pruning studies with field-grown, Autumn-sown varieties have shown that under good growing conditions plants with only a main-stem inflorescence can yield well. However, plants with one level of branching may be expected to provide improved stability of yield across years of less favourable weather.

Plant breeders in France and Poland have recently developed florally determinate plants which produce only one or two flushes of flowers. This material matures earlier and is likely to be more suited to cool maritime climates, some of this material is now available for further physiological and agronomic evaluation. ■



REMOTE SENSING OF CROPS

A UK-France collaboration on measuring crop performance.

Early information about crop yield is of obvious commercial and industrial importance. The Broom's Barn site of the AFRC Institute of Arable Crops Research has developed a forecasting system for sugar beet, based on computer models that derive their data from aerial surveys. Light reflected from the crop is measured with a radiometer, and this in turn depends on the state of growth of the crop. Now Broom's Barn scientists are collaborating with the remote sensing unit of Nottingham University, and with two stations of INRA in France, to refine the data which are collected, and give more accurate predictions. It should become possible to evaluate the health of the crop as well as the density of its foliage.

Measurements are made about four times per growing season using a radiometer, fitted in a helicopter. It measures reflected light in the red and near infra-red wavebands, which in turn indicates the area covered by green leaf and hence the amount of light that the crop is intercepting for photosynthesis. Though the present system gives useful forecasts, it does not take differences in soil colour into account; nor, more seriously, does it allow for changes in leaf colour such as yellowing due to virus infection.

Present studies are examining different combinations of light frequencies, from the visible to the middle infra-red, that could provide data about disease status. For example one combination might give the same figure when aimed at a large crop that was infected and from a small crop that was green; but a different combination of wavebands might give a different reading and comparison of the two sets of data would allow the extent of infection to be inferred. ■

EUROPEAN DATABASE OF FORAGE PLANTS

The largest seed collection of forage plants in Europe is held at the AFRC Institute of Grassland and Environmental Research, Aberystwyth which acts as an agent of the International Board for Plant Genetic Resources to provide the central database for three major forage species that are held in gene banks throughout Europe - *Lolium perenne* (perennial ryegrass), *Lolium multiflorum* (Italian ryegrass) and *Trifolium repens* (white clover).

The database is important for collaborative research, the establishment of "core" collections, characterisation and seed exchange. For example, it allows identification of areas that have already been extensively searched for genetic material (such as northern Italy), and those that have been relatively neglected.

Several countries are involved in this collaboration including - Belgium, Czechoslovakia, France, Greece, Ireland, The Federal Republic of Germany, The German Democratic Republic, The Netherlands, Italy, Poland, Spain and Turkey. Funds are being sought from the EC for further development of the database. Meanwhile, IGER continues to explore Britain and Europe, systematically, to find new forage lines for its own and for other IBPGR gene banks. ■

THE MOLECULAR BIOLOGY OF LACTIC ACID BACTERIA

A four nation study using the latest nucleic acid technology to enhance the characteristics of industrially useful strains and explore new options for food safety and preservation.

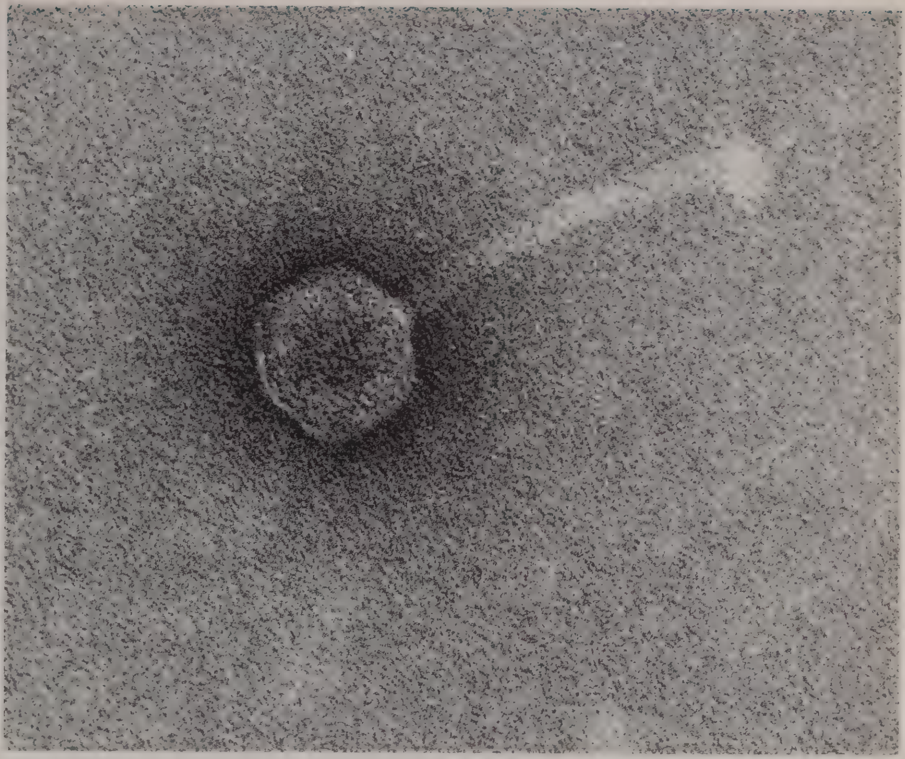
Lactic acid bacteria are used throughout the world in the manufacture of a variety of fermented milk products. Yet they could be improved. Ideally, for example, they would mature cheese more quickly. They could be more resistant to destructive phage viruses - or even be equipped to ward off invasion of pathogens, for example of *Listeria* in soft cheese. They have enormous untapped potential beyond cheese-making, too, in the processing and preservation of other foods. But the lactic acid bacteria are unlike other microbes in many ways and are relatively little understood. If they are to be systematically improved, they must first be studied in greater depth; and the techniques of genetic improvement that have been worked out in other organisms, including those of genetic engineering, must be adapted to their special demands. In collaboration with laboratories in The Netherlands, Ireland, and The Federal Republic of Germany, scientists at the AFRC Institute of Food Research have already made tremendous progress in basic studies of lactic acid bacteria, and in developing techniques for their manipulation; and some of the radical improvements now in train are already the subject of patents.

Interest has focused first on methods of improving lactic acid bacteria by natural "breeding" techniques; involving, in particular, the transfer of the organisms' own plasmids (circles of DNA within the cytoplasm) by which bacteria generally share genetic information. Such "naturally" produced organisms should encounter fewer problems of regulation, as they enter commerce. Scientists at IFR have been equally keen to adapt the techniques of genetic engineering to lactic acid bacteria. First, they have adapted the chemical method for introducing novel DNA that is standard in some other organisms: first stripping the bacterial cell wall with enzymes to create naked "protoplasts" and then forcing DNA in with polyethylene glycol. They have also adapted the technique of electroporation, in which transient holes are punched in the cell membrane of the intact cell with pulses of high-voltage electricity, to allow foreign DNA in the surrounding medium to enter.

The second broad requirement, is to stabilise the novel DNA once it has been introduced. DNA introduced into the bacterial cytoplasm, and incorporated in the plasmids, is liable to be lost as the bacteria multiply. This would clearly be problematical in any industrial-scale fermentation - and is particularly likely to occur because organisms that lack foreign DNA are often at a slight but significant reproductive advantage, over those that are transformed.

One approach at IFR has been to produce host lactic acid bacteria that die unless the novel plasmid is in place. These hosts are mutants whose chromosome is lacking in some essential gene: a gene that is provided within the introduced plasmid. Within a culture of such mutant organisms, those that lose their novel plasmids simply die out. Another approach is to introduce the novel DNA into the chromosome itself in an ordered fashion; an approach furthered by studies of natural transposable DNA elements within the lactic acid bacterial chromosome.

The third strand of the basic technological studies is to characterise the principal genes, and to map the chromosome, so as to facilitate ordered introduction of novel genes. There is a lack of genetic markers in these bacteria, to allow the positions of genes to be easily inferred; so IFR is employing physical methods of exploring the chromosome, by breaking it into fragments and separating them in gel electrophoresis.

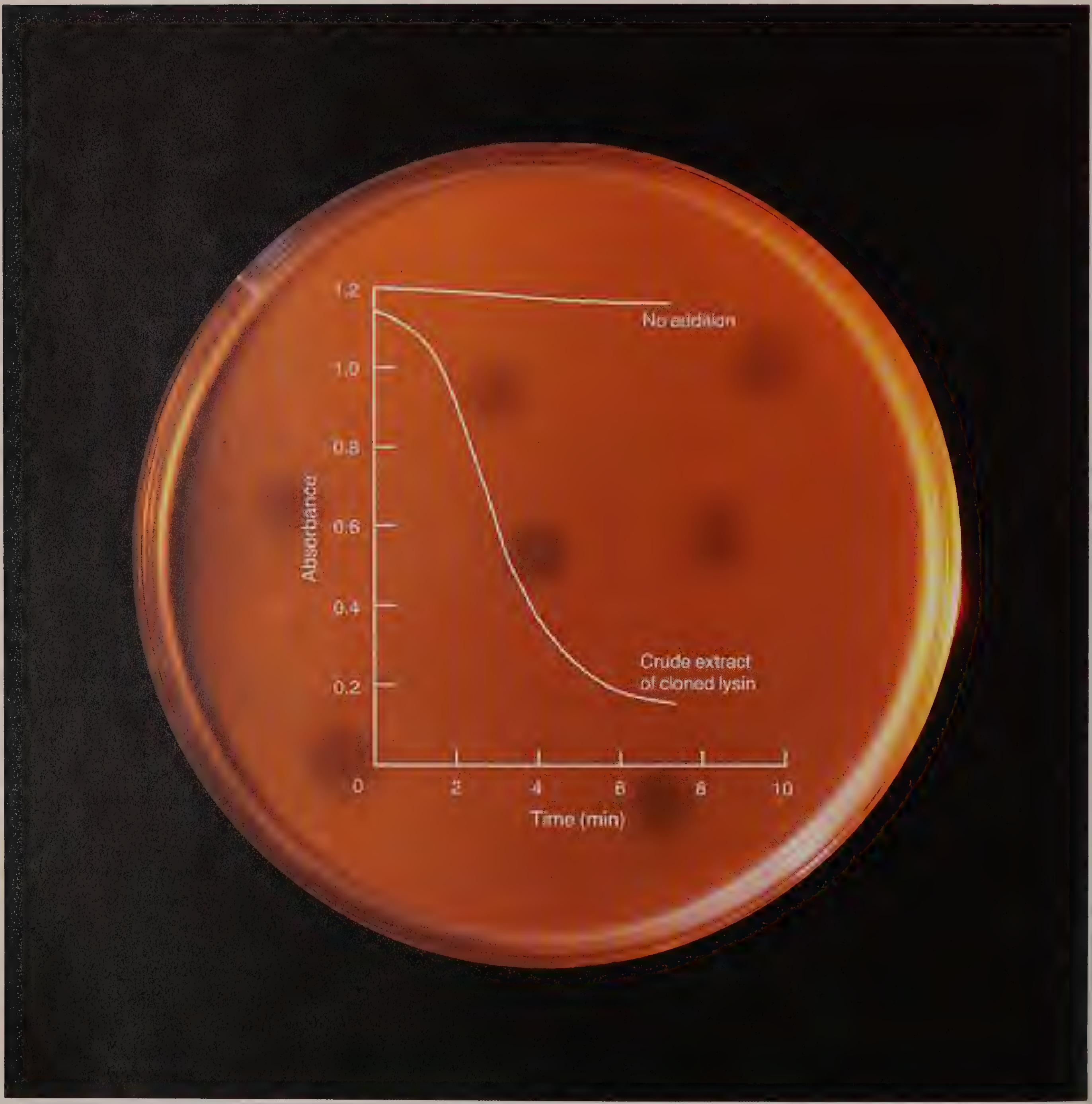


Transmission electron micrograph of prolate–headed bacteriophage.

These basic studies are already suggesting, or are beginning to provide, advances of obvious industrial significance. One is the possibility of "tagging" the bacterial chromosome with prescribed coded sections of DNA, so that future regulatory bodies can distinguish between cell lines that have been given clearance, and cowboy imitations.

A more immediate possibility of enormous commercial potential, is to reduce the maturation time of cheese simply by unfettering the abilities that lactic acid bacteria already possess. In practice, maturation begins after fermentation has ceased. With the lactose now replaced by lactic acid, the bacteria begin to die. As they do they digest their own cells (autolysis); and the flavour-generating enzymes including peptidases are released. One possibility is to increase the amounts of these key enzymes or to improve the enzymes themselves by protein engineering. Another, is to produce lactic acid bacteria by genetic engineering which break up (lyse) as soon as fermentation is finished, and thus release their proteolytic enzymes immediately. To this end, IFR scientists have cloned the gene from a virus which naturally attacks lactic acid bacteria, and causes them to break up. This gene, introduced into the bacteria themselves, could cause those bacteria to break open more quickly after fermentation has ceased, and allow maturation to begin immediately, and at its full rate. Isolation and cloning of the particular lytic gene was essential. The virus itself obviously could not be employed to effect the lysis as it would infect the dairy environment and destroy the starter culture.

Perhaps even more exciting, would be



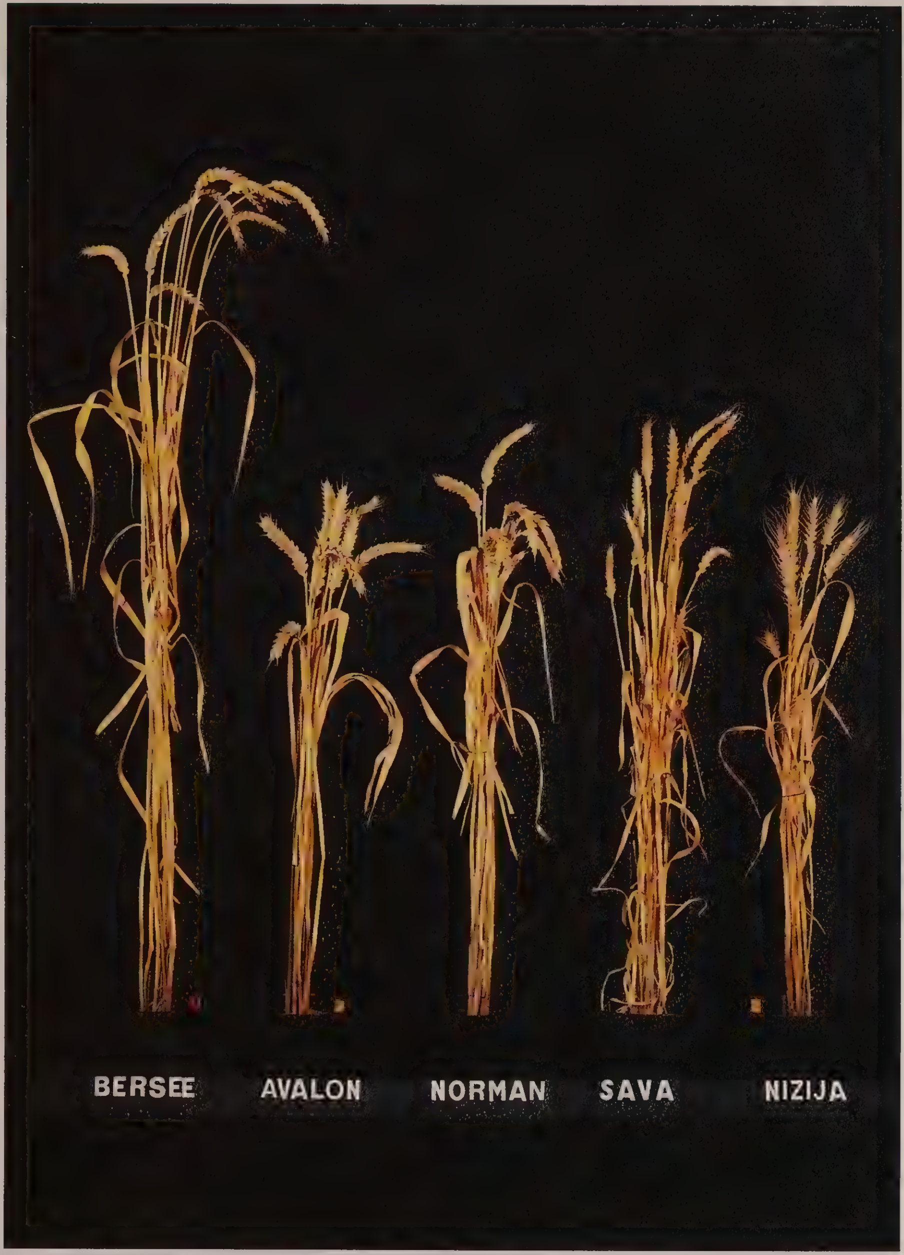
Lysis of starter cells by cloned bacteriophage lysin.

to produce lactic acid bacteria that are able specifically to attack pathogens in food. To this end, IFR researchers have already cloned the gene that produces the antibiotic peptide nisin, produced by lactococci. Lactic acid bacteria expressing this gene could have obvious potential for food safety.

This research is supported by EC funding under the Biotechnology Action Programme, and involves collaboration with the University of Groningen, The Netherlands, Bund. fur Milchforschung, Kiel, Federal Republic of Germany, NIZO, Ede, The Netherlands, and University College, Cork, Ireland. ■

NEW DWARFING GENES FOR BRITISH WHEATS

A collaborative study with Hungarian and Yugoslav scientists.



Final plant height of a tall variety Bersee compared to GA insensitive UK semi dwarf varieties Avalon and Norman and the Yugoslavian varieties Sava and Nizija carrying alternative Akakomuji dwarfing genes.

Modern wheats yield heavily partly because stems kept short by "dwarfing" genes enable them to withstand heavy fertiliser applications without lodging.

Bread wheats have 42 chromosomes, which represent three sets of 14 (7 pairs). Each chromosome set is derived from a different grassy ancestor. They are labelled A, B and D. The dwarfing genes of British wheats are located on chromosomes 4B and 4D. They induce dwarfing by reducing the plant's ability to utilise its natural growth hormone gibberellic acid or GA. As the plant is unable to use all its natural growth hormone applying additional GA at the seedling stage will have no effect on seedling height. Applying GA to seedlings with alternative dwarfing genes or no dwarfing genes causes stem elongation.

Under optimal growing conditions the GA insensitive dwarfing genes present in 80 per cent of Britain's wheats will combine a height reduction with a 20 per cent yield increase. Grown in southern Europe the same dwarfing genes show susceptibility to climatic stress and may even reduce yields. Thus if UK summers become hotter as a consequence of global warming our dwarfing genes could ultimately reduce yields. Scientists at the AFRC Institutes of Plant Science Research Cambridge Laboratory are thus seeking alternative dwarfing genes from among southern European varieties.

The IPSR researchers are examining the semi-dwarfing genes, derived from a Japanese variety, that were introduced into southern Europe varieties 30 to 40 years ago and which are now found in the modern Italian variety *Mara*. Genes that influence height in *Mara* are found on the translocated chromosome 5BS-7BS, and also on chromosome 2D. Of particular interest are two of the genes on chromosome 2D. Trials carried out in collaboration with Yugoslav and Hungarian scientists, have shown that one of these genes reduces plant size, apparently by being less efficient at increasing height than the gene met in most varieties; the other reduces final height because it renders the plant insensitive to daylength. The plant comes into flower in early summer, without needing to be triggered by increasing daylength, as British wheats do. This means that the plant is shorter at the time of flowering, and avoids the worst effects of desiccation met in hot southern European climates. ■

CONTROL METHODS FOR FOOD SAFETY

Collaborative research with Hungary.

Scientists at the AFRC Institute of Food Research are collaborating with workers at the Central Food Research Institute, Budapest to develop combined treatments to control the safety and preservation of foods. The work is aimed specifically at prevention of the survival of, and growth from spores of *Clostridium* spp. The current work in Budapest concerns *Clostridium sporogenes*, a spoilage organism, spores of which are heat-resistant and often determine the heat treatment that must be given in canning or other heat-processing of foods. The aim of the work is to determine the extent to which the composition of foods can be modified to reduce the heat-resistance of these spores, and to develop the combined use of heat and irradiation.

Work at IFR concerns *Clostridium botulinum*, an organism that produces a highly lethal toxin. Spores of proteolytic strains are very heat-resistant and determine the minimum heat-processing that is given to many foods. Proteolytic strains will not grow at temperatures below 10°C, but non-proteolytic strains will grow at temperatures down to 3.3°C. Because of the importance of non-proteolytic *C.botulinum* in relation to chilled foods, the aims of the work at the IFR are to determine the effect of combinations of treatments and inhibitory factors on the survival of spores and on the growth of these bacteria.

Exchange visits between Norwich and Budapest are financed by the British-Hungarian Cooperative Science and Technology Research and Development Programme managed by the Hungarian International Cultural Institute, and the British Council. ■

CEREAL GRAIN DRYING

Collaborative studies with researchers in Poland.

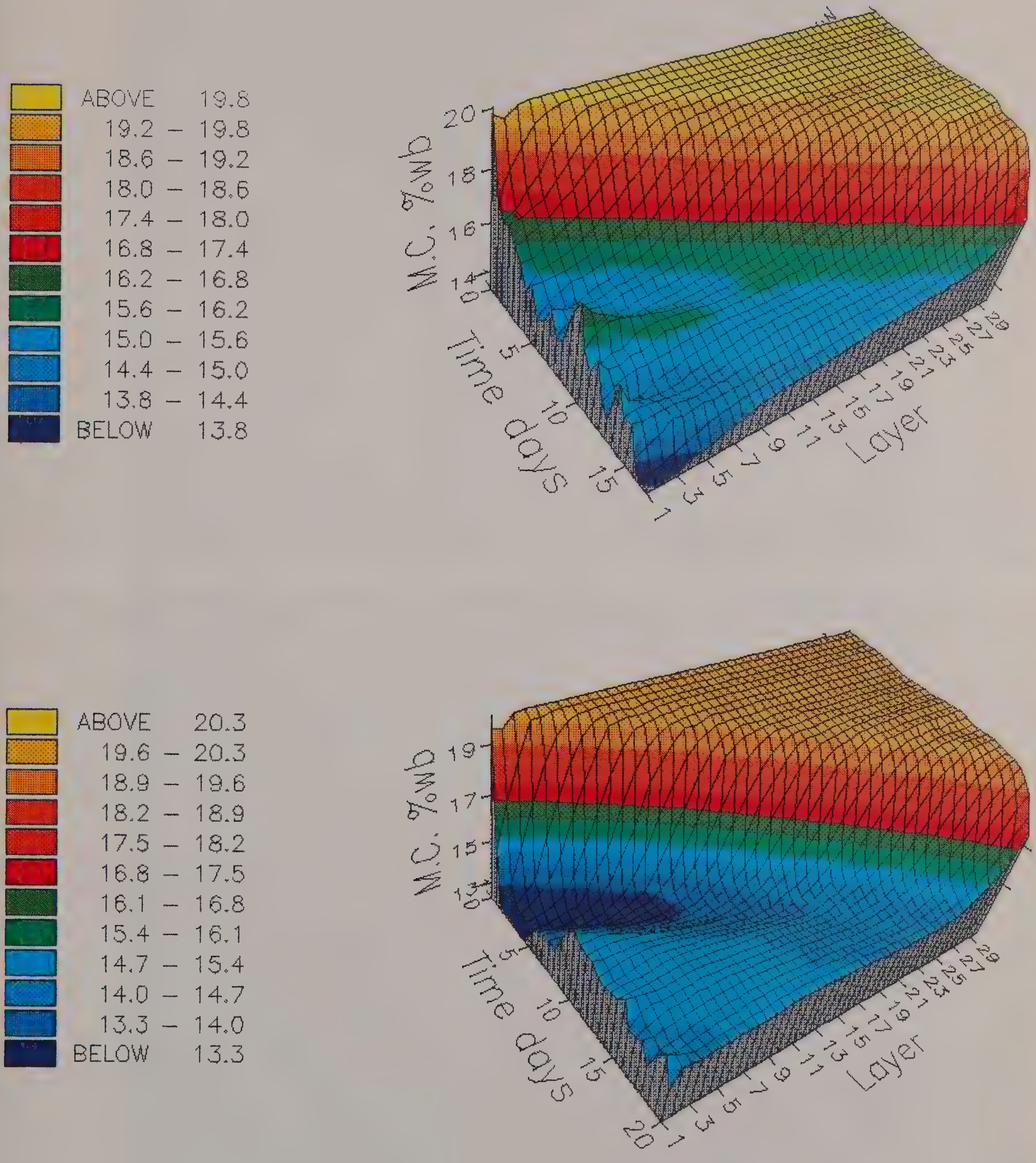
More than half the cereal grain in Britain is dried slowly in a stream of air that is only slightly above ambient temperature, and perhaps (as is increasingly popular) has been dehumidified. If drying is too slow or uneven, then the grain will spoil; if it is more vigorous than is needed, then energy is wasted in driving the fan and heaters. Complex physics is required to find the ideal flow, humidity, and temperature of air; but engineers at the AFRC Institute of Engineering Research have now devised a computer model which they hope will enable farmers to produce adequate, even drying with minimum input of energy - and which suggests that current practice, based on common sense principles, may be the opposite of what is required.

For drying with near ambient air, grain is put in beds one metre to four metres deep, and ventilated from below. Drying, then, begins at the bottom and works up, with the upper layers being bathed in moist air blown up from the layers beneath. The air should be virtually saturated when it leaves at the top, for if it is not, then its capacity for drying is not being exploited to the full. But if it is saturated, then the top layers stay wet for many days (the whole operation may take about 15 days) and so long as humidity remains above 90 per cent, and the temperature is adequate, moulds can grow.

In general, drying is quickest if the airstream is hot, dry, and flowing rapidly, but besides the implied waste of energy, there are many complications. Too rapid drying of the bottom may actually increase the likelihood of mould at the top, as large amounts of moisture rapidly extracted from the bottom, and held as vapour in the hot air stream, may condense in the cooler layers above. Also the initial moisture content of the grain may vary, from less than 18 per cent (which in general should be safe from mould) to more than 22 per cent (which is highly vulnerable); and the ambient air temperature and humidity also vary, from season to season, day to day, and hour to hour.

The computer model shows, in graphic form, what would happen throughout a bed of grain as the relative humidity, temperature, and rate of air flowing through is varied. One of the conclusions is that drying is most even, and grain can be kept free of visible mould and energy input is minimum, if air is first run through both warm and dry, but is then allowed to become cooler and more moist; a system that allows the bottom layers to be overdried, but then to moisten again. Common sense, however, tends to suggest the opposite strategy; to allow the air to be moister at first (when the grain itself is wetter) but then to use drier air as the grain dries.

From an assessment of weather data from five sites in Britain over two decades, AFRC engineers, in collaboration with an engineer from the University of Poznan, Poland have shown that the strategy for drying suggested by their computer model would not have allowed any spoilage of grain in any of the sites, in any year. However, they have yet to test the computer strategies in the field. AFRC engineers are confident they will provide software that will control existing driers (many of which already carry microchips for control purposes), and gear their output precisely to the state of the grain and the temperature and humidity of the air, while running the fans and heaters to their maximum efficiency. ■



Comparison of the progress of drying and final moisture gradient ***(bottom)*** *which allows initial overdrying of the bottom layers to be countered for optimised simple heater control* ***(top)*** *and a more flexible strategy by later rewetting to produce a uniform final moisture gradient.*

FUNDAMENTAL RESEARCH AND THE DEVELOPING WORLD

About 80 per cent of the world's population lives in developing countries, including those of Africa, Latin America, East and South Asia and Oceania (excluding Australia, Japan and New Zealand). In these countries, provision of sufficient food remains the paramount concern, particularly as population is soaring in many of these countries.

Scientific and technological advances, especially in molecular biology, could help to solve many problems of plant and animal diseases and pest attack, that cause major losses in tropical and sub-tropical agriculture. Many of the fundamental research programmes of AFRC offer long-term solutions that could help to sustain the food supply in developing countries.

AFRC scientists are also involved, most often with funding from agencies such as the ODA, British Council and organisations of the United Nations, in the establishment and operation of educational and research training activities aimed at developing both laboratory and field skills for the future. Examples include an internationally supported laboratory course on the molecular genetics and manipulation of *Streptomyces* held in China in 1989. This course, organised by scientists from the John Innes Institute, is relevant to improvement of *Streptomyces* for production of antibiotics, and other secondary metabolites such as antiparasitic agents, herbicides and pharmacologically active compounds, as well as enzymes for the agri-food industry. Another example is a course on plant virus techniques, organised by the AFRC Institute of Arable Crops Research. This course, which covers virus classification, isolation and transmission techniques, diagnosis, epidemiology and basic control methods, has been presented recently in Kenya and in the People's Democratic Republic of Yemen. A one year MSc course in crop protection, offered at the Long Ashton Research Station of IACR, in collaboration with the universities of Bristol and Bath, continues to attract overseas students, many funded through the FAO and ODA.

The Overseas Division of the AFRC Institute of Engineering Research is funded mainly by the ODA. It undertakes research and provides advice and technical assistance to overseas governments, aid agencies, farmers and others involved in rural development in developing countries. The Division works on a mix of advanced and more simple technology. Current topics include: small farm mechanisation, soil and water management, cereal harvesting, draught animal power, computing and software development, energy use in agriculture and tractor mechanisation.

At the AFRC Institute of Arable Crops Research at Rothamsted, the ODA funds a Biometrics Unit which provides advice and assistance to ODA teams abroad and to national and international institutes around the world. An important part of the Unit's work is to advise on the design of statistical methods for analysing experimental data, and the use of computer technology.

Some of AFRC's work in developing countries takes the form of consultancy and technology transfer. Funding is generally by international agencies and overseas governments, or by industry. One example is immunoassay technology, in which expertise from the AFRC Institute of Food Research has been sought in applications to mycotoxins in foods (Cuba) and in analysis of pesticides (China).

Some examples of AFRC research directly relevant to agriculture and food production in developing countries are given on the following pages. They include: identification of protein antigens from the gut of stomach worms which could help development of effective vaccines; investigations of mechanisms of virus infection in plants, which could lead to the transformation of rice plants so that they are resistant to Tungro disease; characterisation and molecular cloning of seed proteins conferring insect resistance in tropical cereals; and new strategies for plant breeding to exploit genes that confer disease resistance, e.g. to halo-blight in *Phaseolus* beans, and natural defence mechanisms against the parasitic weed, *Striga*. We also report on research from the DAFS-funded Moredun Research Institute which has identified the sheep-derived virus that causes malignant catarrhal fever, an important disease of ruminants in Pacific countries.

ECHERCHE ONDAMENTALE ET LE ONDE EN VOIE DE EVELOPPEMENT

viron 80% de la population mondiale vit ns des pays en voie de développement nprenant des états d'Afrique, d'Amérique tine, d'Asie du sud, d'Asie de l'est et d'Océa- (à l'exception de l'Australie, du Japon et de Nouvelle Zélande). Le souci principal de ces ys reste un approvisionnement suffisant en urriture d'autant plus que la population ne se d'augmenter dans la plupart d'entre eux.

progrès scientifiques et technologiques, ticulièrement dans le domaine de la biologie léculaire, pourraient aider à résoudre beau- up de problèmes liés aux maladies végétales animales ainsi qu'à l'invasion des insectes uisibles, responsables de pertes importantes ns l'agriculture tropicale et subtropicale. Beaucoup de programmes de recherche élaborés au sein de l'AFRC proposent des solutions à long terme qui permettraient de maintenir l'approvisionnement en nourriture dans les pays en voie de développement.

Grâce au financement d'agences telles que l'ODA, le British Council et d'autres organisations membres des Nations Unies, les scientifiques de l'AFRC sont aussi impliqués dans l'élaboration et le déroulement d'activités éducatives et de formation dans le cadre du développement de compétences futures dans les laboratoires et sur le terrain. Par exemple, c'est grâce au soutien de la communauté internationale qu'un cours sur la génétique moléculaire et la manipulation des Streptomycètes a eu lieu dans un laboratoire en Chine en 1989. Ce cours a été organisé par les scientifiques de l'Institut John Innes afin d'améliorer les Streptomycètes pour la production d'antibiotiques et d'autres métabolites secondaires tels que les agents antiparasites, les herbicides, les composés pharmacologiquement actifs et les enzymes dans l'industrie agro-alimentaire. Le cours sur les techniques liées aux virus végétaux représente un autre exemple. Ce cours qui comprend la classification des virus, les techniques d'isolation et de transmission, les diagnostiques, l'épidémiologie et les méthodes de contrôle de base, a été organisé par l'Institut de Recherche sur les Produits Agricoles (IACR) et récemment présenté au Kénya et dans la République Démocratique du Yémen. Enfin, le cours de douze mois débouchant sur une maîtrise scientifique en protection des récoltes agricoles a lieu à Long Ashton Research Station (membre de l'IACR) en collaboration avec les universités de Bath et de Bristol. Il continue à attirer de nombreux étudiants internationaux dont la plupart sont aidés financièrement par le FAO et l'ODA.

La Division Outre-mer de l'Institut de Recherche en Génie Agricole, membre de l'AFRC, est principalement financé par l'ODA. Il conduit des recherches et fournit conseils et assistance technique aux gouvernements étrangers, aux agences d'aide, aux fermiers et autres personnes qui participent au développement rural dans les pays en voie de développement. Cette Division travaille sur une base de coopération entre les techniques modernes et les techniques plus traditionnelles. Les sujets à l'ordre du jour sont les suivants: mécanisation des petites entreprises agricoles, gestion de l'eau et des terrains, récoltes des céréales, résistance des animaux à la sécheresse, développement de l'informatique et la consommation d'énergie dans l'agriculture et par l'utilisation des tracteurs.

L'Institut de Recherche sur les Produits Agricoles, basé à Rothamsted, comporte une Unité Biométrique qui fournit conseils et assistance aux équipes de l'ODA à l'étranger ainsi qu'aux instituts nationaux et internationaux de par le monde. L'une des tâches importantes de l'Unité est de fournir des conseils concernant les méthodes d'élaboration et de statistiques pour l'analyse des données expérimentales et pour l'utilisation de l'informatique.

Quelquefois, le travail de l'AFRC dans les pays en voie de développement, prend la forme de consultation ou de transfert des technologies. Le financement provient généralement des agences internationales, des gouvernements outre-mer ou des entreprises. Par exemple, les compétences de l'Institut de Recherche Agro-alimentaire sont souvent requises dans le cadre de l'application de la technologie immuno-analytique au sujet des mycotoxines dans la nourriture (à Cuba) et pour l'analyse des pesticides (en Chine).

Quelques exemples de recherches effectuées par l'AFRC concernant directement les productions agricoles et la nourriture dans les pays en voie de développement, sont présentés dans les pages suivantes. Ils comprennent: l'identification des protéines antigènes provenant des viscères du ver solitaire, qui pourraient mener à la création de vaccins efficaces; les études sur les mécanismes d'infections virales chez les plantes qui pourraient entraîner la modification des plantes de riz afin qu'elles puissent résister à la maladie Tungro; la caractérisation et le regroupement des protéines situées dans la semence des céréales tropicales, déterminant la résistance des insectes; et les nouvelles stratégies de culture végétale pour exploiter les gènes qui permettent la résistance à la maladie telle que le mildiou pour les haricots Phaseoh et qui entraînent les mécanismes de défense naturelle contre la mauvaise herbe parasitaire appelée Striga. Nous présentons aussi un rapport sur les résultats de l'Institut de Recherche Moredun, financé par le DAFS, concernant l'identification d'un virus dépisté dans le mouton causant une fièvre catarrheuse maligne, une maladie qui s'attaque aux ruminants et qui très répandue dans les pays du Pacifique.

RUNDLAGENFORSCHUNG ND DIE NTWICKLUNGSWELT

Ungefähr 80 Prozent der Weltbevölkerung lebt n Entwicklungsländern, die Afrika, Lateinamerika, Ost- und Südamerika und Ozeanien außer Australien, Japan und Neuseeland) einschließen. In diesen Ländern ist die Beschaffung ausreichender Nahrungsmittel weiterhin die größte Sorge, insbesondere deswegen, weil der Bevölkerungszuwachs in vielen dieser Länder stark zunimmt.

Wissenschaftliche und technische Fortschritte, speziell in der Molekularbiologie, könnten helfen, viele Probleme bei Pflanzen- und Tierkrankheiten sowie Schädlingsangriffen, die große Verluste in der tropischen und subtropischen Landwirtschaft hervorrufen, zu lösen. Viele der Grundlagenforschungsprogramme des AFRC (Agricultural and Food Research Council = Rat für Landwirtschafts- und Ernährungsforschung) bieten langfristige Lösungen, die helfen könnten, die Nahrungsmittelversorgung in Entwicklungsländern aufrechtzuhalten.

Wissenschaftler des AFRC sind ebenfalls in der Etablierung und Durchführung von Schulungsaktivitäten für Bildung und Forschung verwikkelt, sehr oft durch Finanzierung von Organen wie die ODA (Overseas Development Administration = Überseeentwicklungsadministration), British Council (Britischer Rat) und Organisationen der Vereinten Nationen, wobei das Ziel die Entwicklung von zukünftigen Labor- und Praxisfähigkeiten ist. Beispiele umfassen einen international unterstützten Laborkursus über Molekulargenetik und Manipulation von Streptomyces, der 1989 in China abgehalten wurde. Dieser Kursus, der von Wissenschaftlern des John Innes Instituts organisiert wurde, ist relevant für die Verbesserung von Streptomyces zur Herstellung von Antibiotika und anderer sekundärer Metaboliten wie antiparasitische Wirkstoffe, Herbizide und pharmakologisch aktive Verbindungen sowie Enzyme für die landwirtschaftliche Nahrungsmittelindustrie. Ein weiteres Beispiel ist ein Kursus über Pflanzenvirusmethoden, der vom AFRC Institute of Arable Crops Research (IACR) (Institut für Ackererntenforschung) organisiert wurde. Dieser Kursus, der Virusklassifikation, Isolation und Übertragungsmethoden, Diagnosen, Epidemiologie und Grundbekämpfungsmethoden einschließt, ist kürzlich in Kenia und in der Demokratischen Volksrepublik Jemen präsentiert worden. Ein einjähriger Kursus über Feldfrüchteschutz mit dem Universitätsabschluß Magister der Naturwissenschaftlichen Fakultät, der in Zusammenarbeit mit den Universitäten von Bristol und Bath an der IACR- Forschungsanstalt Long Ashton angeboten wird, zieht weiterhin Studenten aus Übersee an, wobei viele durch die FAO (Food & Agriculture Organisation = Ernährungs- und Landwirtschaftsorganisation) oder die ODA finanziert werden.

Die Überseeabteilung des AFRC Institute of Engineering Research (Institut für Technische Forschung) wird in erster Linie durch die ODA finanziert. Es führt Forschungen durch und gibt Rat und technische Unterstützung an ausländische Regierungen, Hilfsorgane, Landwirte und andere, die in den ländlichen Entwicklungen der Entwicklungsländer involviert sind. Die Abteilung arbeitet mit einer Mischung von fortgeschrittener und einfacherer Technik. Augenblickliche Themen umfassen: Mechanisierung kleiner Bauernhöfe, Boden- und Wasserverwaltung, Getreideernten, Zugtierkraft, Computer- und Software- entwicklungen, Energieverbrauch bei der Landwirtschafts- und Traktormechanisierung.

Am AFRC Institute for Arable Crops Research in Rothamsted finanziert die ODA eine Biometrie-Einheit, die Rat und Unterstützung an ODA-Teams im Ausland und an nationale und internationale Institute in der ganzen Welt gibt. Ein wichtiger Bestandteil der Arbeit dieser Einheit ist die Beratung bei dem Entwurf statistischer Methoden zur Analyse von Experimentdaten und bei der Anwendung von Computertechnologie.

Ein Teil der Arbeit des AFRC in den Entwicklungsländern ist in Form von Beratung und Übertragung von Technologie. Die Finanzierung findet im allgemeinen durch internationale Organe oder ausländische Regierungen oder durch die Industrie statt. Ein Beispiel ist die Immunversuchstechnologie, bei der man die Erfahrung vom AFRC Institute of Food Research (Institut für Ernährungsforschung) für Anwendungen bei Pilzgiften in Nahrungsmitteln (Kuba) und bei Analysen von Pestiziden (China) ersucht.

Auf den folgenden Seiten sind einige Beispiele der AFRC-Forschung angegeben, die eine direkte Relevanz zur Landwirtschaft und der Nahrungsmittelproduktion in den Entwicklungsländern haben. Sie umfassen: Identifizierung von Protein-Antigenen aus dem Darm der Magenwürmer, was bei der Entwicklung wirkungsvoller Impfstoffe helfen kann; Untersuchungen der Mechanismen von Virusinfektionen in Pflanzen, was zur Transformation von Reispflanzen führen könnte, so daß sie der Tungro- Krankheit widerstehen können; Charakterisierung und Clonen von Molekülen von Saatproteinen, um Insektenresistenz auf tropische Getreide; und neue Strategien für die Pflanzenzucht, um die Gene auszunutzen, die Krankheitsresistenz übertragen, z.B. auf Halo-Braunfäule in Phaseolus-Bohnen und natürliche Verteidigungsmechanismen gegen das parasitische Unkraut, Striga. Wir berichten ebenfalls über die Forschung vom DAFS*-finanzierten Moredun Forschungsinstitut, das den vom Schaf stammenden Virus identifiziert hat, der bösartiges katarrhalisches Fieber hervorruft, eine wichtige Krankheit bei Wiederkäuern in pazifischen Ländern.

*DAFS = Department of Agriculture and Fisheries for Scotland Ministerium für Landwirtschaft und Fischereien für Schottland

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LA INVESTIGACION FUNDAMENTAL Y LOS PAISES EN VIAS DE DESARROLLO

Aproximadamente un 80% de la población mundial vive en países en vías de desarrollo en Africa, Latinoamérica, el Este y Sudeste de Asia y Oceanía (sin incluir Australia, Japón y Nueva Zelandia). En tales países, la provisión de alimentos suficientes continúa siendo una preocupación primordial, especialmente debido al hecho de que la población en muchos de estos países está creciendo a pasos agigantados.

Los avances científicos y tecnológicos, en especial en lo que se refiere a la biología molecular, podrían ayudar a solucionar muchos de los problemas relacionados con las enfermedades y plagas que atacan el ganado y los cultivos, y que causan importantes pérdidas para la agricultura en las zonas tropicales y sub-tropicales. Muchos de los programas de investigación fundamental del AFRC (Agricultural and Food Research Council) ofrecen soluciones a largo plazo que podrían ayudar a mantener el abastecimiento de alimentos en los países en vías de desarrollo.

Los científicos del AFRC también se dedican, en la mayoría de los casos con respaldo financiero de agencias tales como la ODA, el British Council, y organizaciones de los Estados Unidos, al establecimiento y operación de actividades educativas y formativas para la investigación, con el fin de desarrollar capacidades tanto en laboratorio como en campo, para el futuro. Los ejemplos incluyen un curso de laboratorio con financiación internacional sobre el tema de genética molecular y manipulación de Streptomyces, llevado a cabo en China en 1989. Este curso, organizado por científicos del John Innes Institute, se refiere a la mejora de Streptomyces para la producción de antibióticos, y otros metabolitos secundarios tales como agentes antiparasitarios, herbicidas, y compuestos famacológicamente activos, al igual que enzimas para la industria agroalimentaria. Otro ejemplo está dado por un curso en técnicas para los virus en plantas organizado por el Institute of Arable Crops Research del AFRC. Este curso, que cubre la clasificación de virus, técnicas de aislamiento y transmisión, métodos de diagnóstico, epidemiología y control básico, ha sido recientemente presentado en Kenia y en la República Democrática Popular de Yemen. Un curso MSc de un año acerca de la protección de las cosechas, ofrecido por la Long Ashton Research Station del IACR, en colaboración con las universidades de Bristol y Bath, sigue atrayendo estudiantes extranjeros, muchos de los cuales cuentan con el respaldo financiero de ODA y FAO (Organización de las Naciones Unidas para la Agricultura y la Alimentación).

La División Extranjera del Institute of Engineering Research del AFRC cuenta, principalmente, con el apoyo financiero de la ODA, y se encarga de la investigación, asesoramiento y asistencia técnica de los gobiernos extranjeros, agencias de ayuda, agricultores y afines relacionados con el desarrollo rural en los países en vías de desarrollo. La División trabaja con una combinación de tecnología avanzada y tecnología más simplificada. Los tópicos actuales incluyen: la mecanización de fincas de pequeño tamaño, manejo de aguas y tierras, cosecha de cereales, potencia de animales que soportan la sequía, desarrollo de computerización y software, uso de energía para la agricultura, y mecanización de tractor.

En el Institute of Arable Crops Research del AFRC en Rothamsted, la ODA subvenciona una Unidad de Biometría que proporciona asesoramiento y asistencia a los equipos de la ODA en el extranjero y a institutos nacionales e internacionales en todo el mundo. Una importante parte de la labor de la Unidad reside en asesorar acerca del diseño de los métodos de estadísticas para el análisis de los datos experimentales, y el uso de tecnología de computador.

Parte de la labor del AFRC en los países en vías de desarrollo toma la forma de consultoría y transferencia de tecnología. La financiación generalmente se recibe de agencias internacionales y gobiernos extranjeros, o de la industria. Un ejemplo está constituido por la tecnología de inmunoensayo, para lo cual se ha requerido la pericia del Institute of Food Research del AFRC en relación con las aplicaciones de micotoxinas en alimentos (Cuba) y el análisis de pesticidas (China).

En las siguientes páginas brindamos algunos ejemplos de la investigación realizada por el AFRC directamente relacionada con la agricultura y la producción alimentaria. Tales ejemplos incluyen: identificación de antígenos de proteínas a partir de las vísceras de parásitos estomacales, lo cual podría ayudar a desarrollar vacunas eficaces; investigaciones acerca de los mecanismos de las infecciones virales en las plantas, lo cual podría llevar a la transformación de las plantas de arroz para que sean resistentes al Tungro; caracterización y clonamiento molecular de las proteínas de las semillas para proporcionar resistencia a los insectos a los cereales tropicales; y la nueva estrategia para el cultivo de plantas mediante la explotación de los genes que transmiten resistencia a las enfermedades, por ejemplo, contra la plaga de aureola en las judías Phaseolus, y mecanismos de defensa natural contra la hierba parasitaria Striga. También informamos acerca de las investigaciones del Moredun Research Institute, con apoyo financiero de DAFS, donde se ha identificado un virus derivado de las ovejas que causa fiebre catarral maligna, importante enfermedad de los rumiantes en los países del Pacífico.

ANIMAL HEALTH

VACCINES AGAINST PARASITIC NEMATODES

Lambs and pregnant ewes worldwide can be killed by severe infestations of the "barber's pole worm", *Haemonchus contortus*, that lives in the stomach and feeds upon capillary blood. Many strains are now resistant to nematicides and vaccines based on live, attenuated larvae do not work. A new approach is needed. Scientists at the AFRC Institute of Animal Physiology and Genetics Research at Cambridge have isolated proteins from the gut of *Haemonchus* which stimulate a protective immune response in sheep.

The work began with electron microscopy, which revealed structures in the gut of *Haemonchus* which proved to be polymers of a protein (contortin). Study of this protein led to another one (H11) in the microvilli membranes. When these proteins are injected into sheep, the animals produce antibodies against them which pass into the nematodes' gut via the blood on which the worms feed. These antibodies then interact with the nematodes' gut surface. Injection of microgram quantities of H11 reduced subsequent experimental infection by 90 per cent and in many animals, infestation was eliminated entirely.

This work is being conducted in collaboration with the DAFS-funded Moredun Research Institute, where parallel studies on other economically important sheep worms are being carried out. Work at both institutes is supported by Pitman-Moore. Studies are underway to identify the precise sequences within the proteins that elicit the immune response, so that they may be cloned for development of an effective vaccine. The principle should also prove effective against hookworms, which infest around 750 million people worldwide. ■

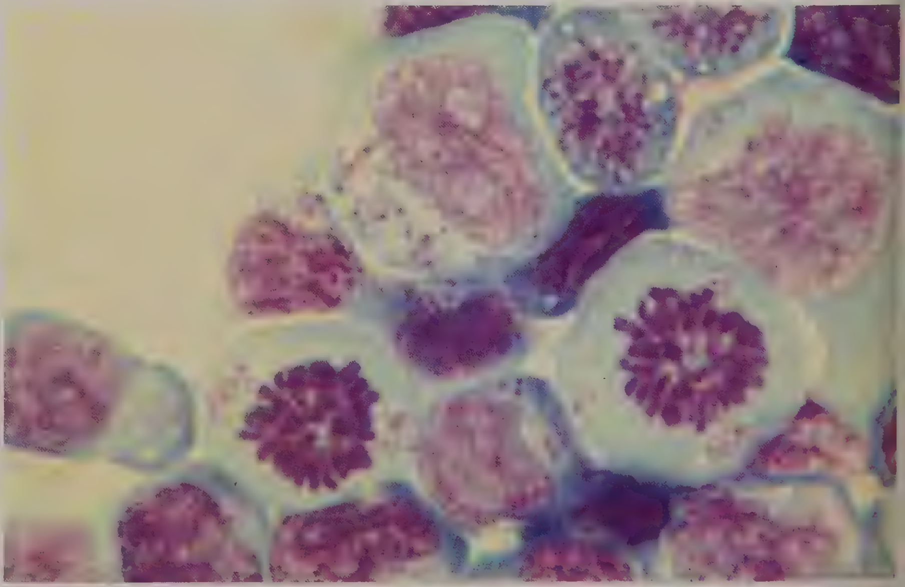
MALIGNANT CATARRHAL FEVER

Malignant catarrhal fever, MCF, is caused by herpes viruses carried by sheep and (a different strain) by wildebeest, doing no harm to their principal hosts but causing severe outbreaks among domestic deer, captive ruminants in zoos, and some cattle - including, importantly, banteng in Indonesia and water buffalo throughout the Pacific Basin.

The wildebeest MCF virus was isolated in the 1960s. Scientists at the DAFS-funded Moredun Research Institute in collaboration with researchers in Indonesia, are now isolating and characterising the sheep-borne virus for the first time. This research, which is supported by the ODA, should help in the development of control strategies.

The Moredun scientists have isolated a subset of lymphoblastoid cells from the immune systems of diseased animals, which can be cultured more or less indefinitely. Study of these infected cells has indicated that the virus may alter the production of interleukins in infected cells, thus affecting the behaviour of the immune system in different ways. Such a mechanism would account for the enormous variation in the disease, between and within species. In cattle, for instance, the disease classically causes severe running of the nose and eyes, and MCF in cattle is certainly under-diagnosed; but in deer causes haemorraghic enteritis. The outcome, presumably, depends on the particular subset of lymphoblastoid cells that are infected. This helps to explain the elusiveness of the sheep-derived virus; only a few cells are infected, and in animals that show signs of the disease it is possible that only part of the virus genome is retained.

Parallel studies on the wildebeest virus have shown that part of its DNA is homologous with DNA from infected lymphoblastoid cells from cattle and deer. This provides a probe to expose the sheep-derived virus and part of the sheep virus DNA has now been cloned. With this, it will at last be possible to identify the virus within sheep, and discover how it is passed on. This should allow rational approaches to therapy or prevention. ■



Stained preparation of a lymphoblastoid cell line derived from a cow with malignant catarrhal fever (MCF). The cells express T–lymphocyte surface markers and contain genome of the sheep herpesvirus which causes MCF.

FOOT-AND-MOUTH DISEASE

Foot-and-Mouth Disease Virus (FMDV) is highly infectious and causes one of the world's most economically important diseases of domestic animals. Its basic molecular biology is being explored in a new Linked Research Group between the Laboratory of Molecular Biophysics at the University of Oxford and the Pirbright Laboratory of IAH.

The three-dimensional structure of FMDV has recently been determined at the Oxford Laboratory, and a prime objective of the Linked Research Group is to analyse regions on the protein shell, or "capsid" of the virus which elicit antibody response, and thus can be used in the construction of a recombinant vaccine. In collaboration with scientists at the University of Reading, it has been shown that grafting an antigenic FMDV peptide into another "carrier" virus (in this case poliovirus) can produce chimaeric polioviruses capable of stimulating antibody production against FMDV. Exploration of the fine structure of the virus-antibody contact regions of FMDV should also aid understanding of the structural basis of antigenic variation, enable predictions to be tested concerning the effects of mutations on the virus, and aid the design of specific virus inhibitors.

The Linked Research Group is also exploring the molecular basis and genetic control of several aspects of the life cycle of the virus including the processing and assembly of subunits of the protein capsid, and the encapsidation of the RNA genome.

The research team at Pirbright is also collaborating on aspects of the genetic engineering of FMDV with laboratories across Europe within the CEC's co-ordinated programmes on biotechnology (BAP and BRIDGE).

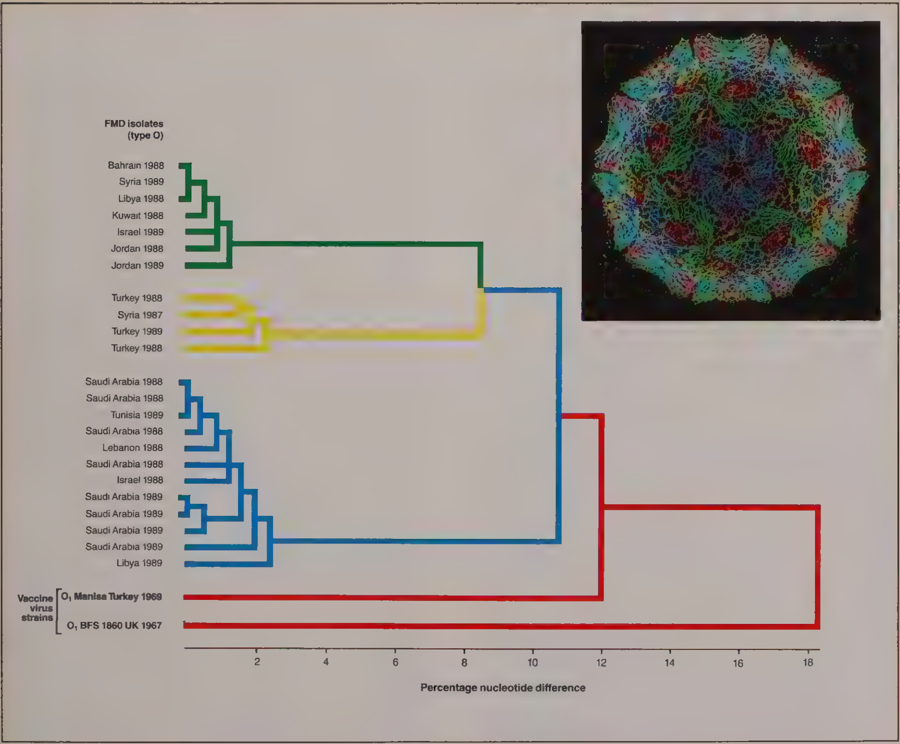
The Pirbright Laboratory is the OIE/FAO World Reference Laboratory for Foot-and-Mouth Disease (FMD). As such, it maintains surveillance over the distribution of the disease worldwide; samples being submitted from all suspect cases of vesicular disease are sent to Pirbright under special import licence.

The Laboratory is always developing new techniques to improve the specificity, sensitivity and speed of diagnosis. It is anticipated that monoclonal antibodies will be used increasingly in the future, and the nucleotide sequences coding for the specific antigenic sites are being identified using virus escape mutants. The polymerase chain reaction (PCR) is being investigated as a rapid diagnostic technique for showing FMD virus RNA in tissue and semen samples.

During the past two years the Pirbright scientists have received a large number of samples from the Middle East and North Africa. The predominant serotype has been type O, the only other serotype being Asia 1 from Oman and Israel. The outbreaks in Tunisia, Libya and Algeria were the first in those countries for a number of years whilst the samples from the Arabian Peninsula, Jordan, Syria and Turkey represent only a small percentage of the total number of outbreaks in this FMD endemic area.

The movement and maintenance of FMD in the Middle East is partly due to large scale movement of animals along trade routes. Sheep, goats and cattle are brought in from India, either direct or via Pakistan, Iran and Turkey collecting additional animals en route, or from East Africa, and even occasionally from the Far East, such as Bangladesh. All these countries have endemic FMD, and the potential for the introduction of exotic serotypes and the generation of antigenically new strains of FMD is enormous.

European livestock will be increasingly at risk from 1991 when vaccination against FMD is formally abandoned. There is FMD in North Africa and the Middle East, and it remains to be seen whether the buffer zone in Turkey can continue to function as efficiently as before. In addition, changes in Eastern Europe and a possible consequential increase in movement of animals and people could lead to introduction of FMD from Central Russia. ■



Sequence of the genetic material identifies related groups of FMD viruses, and can be used to determine how outbreaks spread. The relationship between any two viruses or groups of viruses is given by the furthest vertical line which links them.

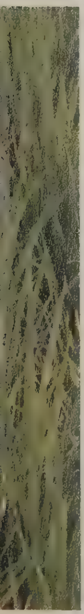
Inset: *The detailed structure of the FMDV shell or "capsid", which contains over* 10^5 *amino acid residues. Here, the peptide backbone of the four protein subunits are traced in blue, green, red and yellow. The capsid is made up of 12 pentamers, a pentamer comprising 5 copies of each subunit. Photo: courtesy University of Oxford, Department of Molecular Biophysics.*

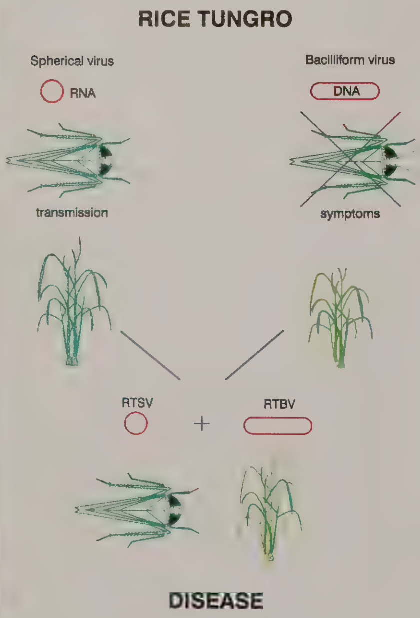
CROP PROTECTION

TOWARDS TUNGRO-RESISTANT RICE

Tungro, the most important virus disease of rice and arguably one of the most important of all plant virus diseases, involves what is effectively a symbiotic relationship between a DNA virus and an RNA virus. The RNA virus alone can be transmitted by the leafhopper vector, but gives no symptoms. The DNA virus can replicate independently and causes severe symptoms, but on its own is not leafhopper transmitted. In spite of research over many years there is no reliable resistance to tungro.

Research at the John Innes Institute is identifying ways of interfering with virus infections and thereby making new forms of virus resistance. Viruses might, in principle, be inhibited at various stages in their infection cycle, e.g. replication within the cell, movement from cell to cell or transmission from plant to plant.





Left: Rice plants in a rice paddy in the Philippines, infected with the rice tungro disease.

Above: Diagrammatic representation of the tungro disease complex. A spherical virus containing RNA is transmitted by a leafhopper, but causes few symptoms. A bacilliform virus containing DNA can cause severe symptoms but cannot be independently transmitted. The transmissible infectious disease results from the interaction of the two viruses.

The general strategy for inhibition is "to turn the virus against itself". The plants would be transformed with genes or nucleic acid sequences derived from the virus itself - either unchanged, or deliberately mutated. The virus gene, inserted into the plant's DNA, would produce a protein that blocks some critical mechanism, or acts as a "decoy", to turn the mechanism off course. Alternatively, the integrated DNA (or RNA produced from it) may provide the required diversion.

Obviously, to develop these resistance mechanisms, one has to have knowledge of how the viruses function. Little information is yet available for the tungro viruses but scientists at JII have already made clones from the nucleic acid of each virus including infectious clones of the DNA virus. These will be used to gain a detailed understanding of the viruses.

In the meantime, other better understood viruses are being used to develop these non-conventional forms of resistance. Cauliflower mosaic virus (CaMV) is a useful model as it is very similar to the DNA tungro virus. It is being used to study the possibilities of interfering with the cell-to-cell spread of such viruses. One of the CaMV genes produces a protein of molecular weight about 38,000 (38K) which, during viral infection, has been shown to locate around plasmodesmata. Plasmodesmata are cytoplasmic channels that run through cell walls and are the likely conduits for cell-to-cell movement of the virus. It is thought that the 38K protein interacts with one or more specific receptor proteins within the plasmodesmata. If this interaction can be unravelled it will be possible to interfere with it thus preventing the virus from spreading from the initially infected cell. Plants could be fitted with a mutant gene that produces proteins similar to the receptor sites on the plasmodesmata; these proteins would smother the recognition sites on the virus. Alternatively, the plant could be fitted with a gene derived from the 38K protein which would attach to plasmodesmata and block the recognition sites.

Another approach could be to interfere with virus replication. Replication of viral nucleic acid involves polymerase enzymes, at least parts of which are encoded by the virus. Plants could be fitted with lengths of nucleic acid that mimic the recognition sites for the polymerase within the viral DNA or RNA; these would mop up the polymerase and, even if replicated, would not produce infectious virus. There is, therefore, a strong need to understand replication in detail in order to know which molecular spanner to throw into the works.

Thus, there are various stages in developing non-conventional resistance to viruses. The systems are being developed with well understood viruses, which are sometimes of limited economic importance. Concurrently, the basic information is being accumulated on more intractable viruses of great economic importance. As well as rice tungro viruses other important viruses such as those which cause African cassava mosaic and maize streak diseases are being studied at JII.

The work on tungro is being conducted in part by collaboration with the University of Nottingham and Washington University, St Louis. It is supported by the Rockefeller Foundation, ODA (NRI), and the Gatsby Foundation and is involving links with the International Rice Research Institute in the Philippines and with researchers in other parts of SE Asia. This research will provide basic information on the functioning of viruses which could prove useful in building resistance into crops grown in the UK. ■

A NOVEL PROTEIN PROTECTING AGAINST PESTS AND DISEASE

Cereal grains contain numerous proteins which act as enzyme inhibitors. Similar inhibitors also occur in other plants where they may be present in healthy tissue, or be synthesised in response to tissue damage or invasion, and form part of the plant's defence mechanisms. Scientists at the AFRC Institute of Arable Crops Research at Long Ashton, in collaboration with researchers in the University of Durham and the University of Ceara (Fortaleza, Brazil) have isolated and characterised a protein from the tropical cereal *Coix lachryma-jobi* (Job's Tears) which is not only an inhibitor of α-amylase from the gut of locusts but is also an enzyme, which can digest fungal chitin.

This is the first demonstration of a protein with activity both as an enzyme and as an enzyme inhibitor. It suggests that this protein plays an important role in protecting the seed against feeding insects and from attack by fungi. The genetic engineering of the gene encoding this protein into major seed crops could offer an attractive means of combating post-harvest damage of stored seeds.

The important clue to the activity of this unusual protein came when the IACR scientists who were examining its α-amylase inhibitory properties, recognised that the amino acid sequence showed an unexpected and close homology with those of known endochitinase enzymes from various sources including barley seeds, and leaves of tobacco, potato and beans. When the *Coix* protein was incubated with fungal chitin it did indeed exhibit chitinase activity.

The manipulation of the gene which gives rise to a protein which is potentially both an "insecticide" and a "fungicide" could benefit UK seed crops. ■

The tropical cereal Coix lachryma–jobi.

COMBATING PESTICIDE RESISTANCE IN INSECTS

Since pests seem bound to develop resistance to any pesticides sooner or later, minimising the build-up and spread of resistance is crucial to maintaining effective chemical control. Sponsored by Ciba-Geigy, scientists at the AFRC Institute of Arable Crops Research at Rothamsted have developed "field simulation" chambers, that enable the response of pests to pesticide to be studied and quantified under realistic conditions.

So far, studies have focused on resistance in the whitefly, *Bemisia tabaci*, which attacks cotton and vegetable crops. The simulation chambers contain several cotton plants at a temperature of 27-29°C to which pesticide is delivered from an overhead sprayer in precisely controlled doses. Even if a resistant insect is not killed it may be irritated and move away from the crop, and so be controlled. Conversely, non-resistant insects under the leaves may escape the spray. In the simulation chambers, these effects can be studied by direct observation and by counting insects present using endoscopes.

One immediate concern is how far the whitefly problems on cotton are due to increased resistance to pesticides, or to destruction of natural enemies, notably of parasitoid wasps. Studies in the chambers being funded by ODNRI and in collaboration with the Commonwealth Institute of Biological Control should help to resolve this. ■

Tobacco whitefly (Bemisia tabaci).

DISEASE RESISTANCE IN *PHASEOLUS* BEANS

Exploiting naturally occurring resistance offers the best hope for protecting beans *(Phaseolus vulgaris)* from the halo-blight bacterium, *Pseudomonas syringae pv. phaseolicola*. Research at the former AFRC Institute of Horticultural Research at Wellesbourne is identifying different races of the pathogen and corresponding sources of resistance in different bean cultivars. Seeds of resistant cultivars have been distributed to national breeding programmes in nine African countries.

It has long been known that some bean cultivars show resistance to certain strains or races of the pathogen but the pattern of resistance has been confusing and it has been difficult to devise rational breeding programmes to incorporate the most appropriate sources of resistance.

Resistance operates on a gene-for-gene basis: particular races of the pathogen carry specific avirulence (A) genes which prevents their ability to cause disease in plants carrying corresponding resistance (R) genes. Avirulence genes seem to place their possessors at a disadvantage - and their existence is a mystery. The halo-blight race that carries no avirulence genes is the most widespread, and probably the most abundant worldwide. However, it is not dominant in every habitat. In Central Africa it is less important than two other races, both of which carry avirulence genes. Part of Wellesbourne's brief is to identify the ecological reasons why different races succeed in different locations.

It is now clear that there are at least nine naturally occurring halo-blight races. Their interaction with resistant cultivars can be explained on the basis of 5 matching gene pairs (R/A genes). Screening of *Phaseolus* accessions from gene banks using a complete set of avirulence genes has identified many new sources of resistance. Many of these are race-specific but a few confer resistance to all races (race non-specific). The corresponding epidemiological studies are showing where in the world each resistance gene or gene combination is most needed. This project involves collaboration with CIAT, Colombia, and with Wye College, University of London and is funded by ODA.

Expertise developed in the genetics of pathogenicity in *Phaseolus* halo-blight should also prove useful in research programmes of more direct relevance to the UK. ■

Halo–blight in Lesotho.

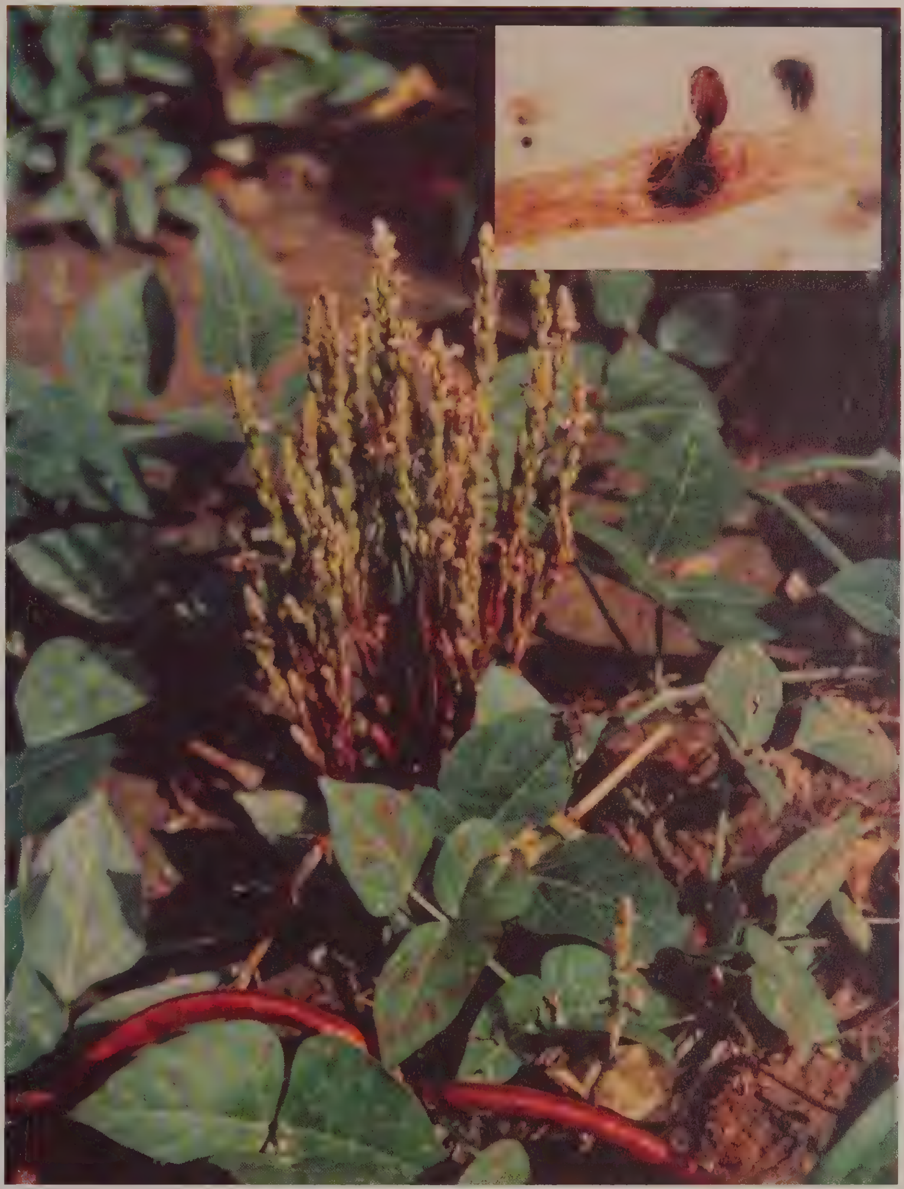
DEVELOPING *STRIGA*-RESISTANT CROPS

Striga, a relative of the antirrhinum, is a parasite that grows on the roots of major food crops of low input farming systems of the semi-arid tropics: devastating millet, sorghum, maize and cowpea. Conventional methods of control (e.g. herbicides) tend either to be too expensive or impractical, and the only feasible approach is to develop resistant varieties. Partially resistant sorghums and millets are being developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India and West Africa. The International Institute of Tropical Agriculture (IITA) in Nigeria is breeding tolerant hybrids of maize. However, the only absolutely resistant crops are varieties of cowpea. Resistance in cowpeas is being explored at IACR, Long Ashton, through a grant from ODA(NRI) and in collaboration with IITA; using methods that could greatly accelerate the breeding of other *Striga*-resistant crops.

The species that attacks cowpea is *S. gesnerioides.* Several varieties of cowpea have recently been identified that show resistance. Two of these, 58-57 and Suvita-2, were found at IITA; a third, B301, originated in Botswana, and investigations at Long Ashton revealed the absolute resistance to *Striga.* Suvita-2 is resistant to *Striga* from Burkina Faso, but is susceptible to strains from Niger, showing that *S. gesnerioides* exists as different strains. B301 is resistant to *Striga* from throughout West Africa.

On susceptible cowpeas, the *Striga* radicles penetrate the host root four to six days after germination, and two or three days later tubercles form at the site of penetration. From these tubercles, the *Striga* shoot emerges.

With 58-57, the parasite seedlings develop normally at first, but the site of penetration becomes necrotic within two or three days; the parasite dies, and no tubercles form. Occasionally this happens with B301. More usually with this cowpea tubercles form but they fail to develop, and no shoot emerges.



Cowpea infested with the parasitic weed Striga gesnerioides *in Mali, West Africa. Severe* Striga *infestations can result in total yield loss. Each* Striga *plant can produce up to 90,000 seeds to infect future crops.*

Inset: *Resistance expressed 2–3 days after penetration of a cowpea root by* Striga gesnerioides. *Necrosis of the cowpea root around the* Striga *leads to failure of parasite development and subsequent death.*

It has been proposed that the partial resistance of some sorghum derives from a failure to produce agents from the root that stimulate germination of parasite seeds. Such a mechanism, however, has not been found to operate in resistant cowpeas - which did allow both germination and penetration. It is clear, too, that 58-57 and B301 employ different mechanisms of resistance. This suggests that cowpeas contain at least two different resistance genes; and further exploration may reveal many more. ■

AFRC - A STRUCTURE FOR THE 1990s

THE RESEARCH BASE: INSTITUTES AND UNIVERSITIES

Council continues to ensure that research conducted in its own institutes and in universities and polytechnics is co-ordinated, and linked where appropriate to obtain maximum scientific value and long-term benefit to the UK agricultural and food research base.

During 1989/90, new methods of assessment of programmes have been introduced, including computer-assisted decision making, and continued efforts made to ensure the work of AFRC is developed alongside that of the other Research Councils in a national context, and also internationally.

The new laboratory of the AFRC Institute of Food Research under construction on the Whiteknights campus of the University of Reading.

INSTITUTES

AFRC remains committed to the further development of its institutes as internationally recognised centres of excellence and to ensuring maximum research output and use of resources by minimising overheads.

AFRC has completed its proposals for restructuring its institutes onto fewer sites, as outlined in the 1989-94 and 1990-95 Corporate Plans, with the announcement of its plans to establish the AFRC Institute of Grassland and Environmental Research on a major centre at Aberystwyth, with sites also at North Wyke and Bronydd Mawr. It is proposed that the ADAS facilities located at the Trawsgoed experimental husbandry farm will be transferred to the new institute, and these resources will provide a basis for work on animal science programmes, particularly on ruminants. The new institute will help to ensure that Britain retains an internationally competitive research capability in the basic and strategic sciences that underpin important environmental and conservation aspects of grassland management and ruminant animal production. The re-organisation is due to be finished in 1992 when the new facilities at Aberystwyth are ready.

The Poultry Department of the former AFRC Institute for Grassland and Animal Production at Edinburgh transferred to the AFRC Institute of Animal Physiology and Genetics Research, with effect from April 1990. The AFRC Laboratory of Molecular Signalling (formerly the Unit of Insect Neurophysiology and Pharmacology) at the University of Cambridge transferred from the AFRC Institute of Arable Crops Research to the AFRC Institute of Animal Physiology and Genetics Research, also in April 1990.

To maintain the competitiveness of the AFRC institutes, it is essential that they are equipped to international standards. Major building and refurbishment programmes integral to the restructuring policy are well underway. The new AFRC Institute of Food Research building on the Whiteknights campus of the University of Reading is scheduled for occupation in August 1991. The new building will comprise two laboratory wings, each housing two scientific departments and an "administrative" block. New laboratory accommodation for over 100 scientists and support staff at the Compton site of the AFRC Institute for Animal Health, is scheduled for completion by 1992 when scientists will relocate from the Houghton site. A start has been made to improve facilities at the Pirbright site of IAH and extensive redevelopments are planned at all its sites. ■

HIGHER EDUCATION INSTITUTIONS

The Council's research grant schemes are revised as necessary to meet new demands. Developments during 1989/90 included a New Investigator scheme, designed to support younger research workers in HEIs, and an equipment grant scheme - totalling £1.4M - to help ensure access to state-of-the-art equipment and research facilities.

The Council's policy is to award individual project grants in any relevant area of high quality science, but also to support co-ordinated programmes in larger groups in priority scientific areas. The AFRC Centre for Animal Genome Research has been established at the University of Edinburgh under Professor Richard Lathe. Two new Research Groups have been set up: the AFRC Unit of Ecology and Behaviour under Professor John Krebs FRS at Oxford; and the AFRC Research Group in Plant Gene Regulation led by Professor Don Grierson at Nottingham.

CO-ORDINATION AND COLLABORATION

Many of the programmes supported are co-ordinated between institutes and universities.

The Transgenic Animal Programme, which involves 97 scientists from institutes and universities, was reviewed in March 1990, showing considerable progress in the present research - and identifying possible further developments. The £14M Plant Molecular Biology programme is now fully established; initial co-ordination meetings have been held of the 80 groups participating, building up the research community. There is extensive international collaboration. Plans are well developed for the new co-ordinated programme in the Biology of Spongiform Encephalopathies which will start early in 1991.

Linked Research Groups provide another valuable mechanism for supporting collaborative research between institute scientists and those based in universities. AFRC has more than doubled the number of Linked Research Groups since 1987/88 to a total of 88. During the year under review, 19 new Groups were established, together with four new Cooperative Research Grants for industry/university collaboration.

Oxford University farm and field station where intensive studies of wildlife populations in the agricultural environment are taking place.
(photo: Mike Amplett, Dept. of Zoology, Oxford).

Research is planned collaboratively with the other Research Councils and other bodies, where this leads to a greater total effort. The Joint Agriculture and the Environment Programme (JAEP), sponsored by AFRC, ESRC and NERC, held its first conference in April 1990, which is being followed by smaller co-ordinated meetings as the programme develops. The AFRC sponsored element deals with plant/herbivore interactions. To help ensure co-ordination of research in biotechnology, AFRC has joined the Biotechnology Joint Advisory Board, which also involves SERC, DTI and NERC.

INTERNATIONAL EXCHANGE

Building upon its strong collaborative links with the French Institut National de la Recherche Agronomique (INRA), AFRC has agreed to establish a joint AFRC/INRA postdoctoral fellowship scheme to support work in defined high priority areas.

AFRC administers two charitable funds that promote international exchanges of scientists. The Wain Fund provides grants for members of staff of UK universities to work overseas, and Fellowships for study abroad by academic staff of universities, including those who have recently completed postgraduate training and expect to enter a research career. Income from the fund for 1989/90 amounted to £31,671. Under this fund visits have been made to USA, Spain, Canada, Switzerland and Australia. The Underwood Fund provides grants for distinguished overseas scientists to visit the UK and undertake research. This has supported visits of scientists from China, Spain, USA, New Zealand, Argentina, Japan, Hungary and Israel. Income from the fund for 1989/90 was £40,223. ■

EDUCATION AND RESEARCH TRAINING

The Council is very conscious of the need for trained manpower in the biological and related sciences. To help secure the science base of the country, and to meet the needs of the private and public sectors, good quality graduates must be attracted into further training, and subsequently retained in scientific careers. There is some evidence that in the biological research sector, which underpins agriculture, food and other industries, this is not being achieved.

This is a national issue which is being considered from a wider standpoint than that of AFRC alone. But the Council is anxious to play its part, and to help ensure that the funds available are spent in the most cost-effective way to overcome these difficulties. Activity during the year under review has included:

At undergraduate level

AFRC's remit does not cover undergraduate support but it is at this level - and earlier - that interest in research can be engendered. Several AFRC institutes have links at undergraduate level with universities, polytechnics and colleges (HEIs) providing an input to taught courses, and the opportunity to see research in progress.

At graduate level

The Council's planned expansion of research studentships has continued, with a further increase of 40 awards during the year. There are now 190 AFRC research students located in HEIs and institutes, with approximately a further 200 in AFRC institutes supported by other bodies. Some are joint awards with industry.

A £600 increase in the studentship stipend was introduced from October 1989 - and a further increase has already been announced from April 1991. Council is still concerned that the level of stipend is not attracting the most able graduates, and is considering how it can be increased further, perhaps with differential rates according to national need etc. Council is also looking at the purpose and adequacy of the Research Training Support Grant.

There is a special need to encourage veterinary graduates to go into research, and revisions have been made to the Council's Veterinary Fellowship scheme to ensure its continuing effectiveness.

Council has reviewed its policy on support of MSc courses, to meet demands such as those of "converting" a graduate from one discipline to another and of providing training for industry and "public good" areas in which manpower requirements cannot be met sufficiently at graduate or postdoctoral level.

At postdoctoral level

The Council has launched its Postdoctoral Fellowship scheme, enabling the most able postdoctoral workers to devote five years to research in HEIs or institutes with stability of funding and a significant level of support costs (starting at £25,000 pa). The first fellows will take up their awards towards the end of 1990.

The many research assistantships funded on AFRC research grants in HEIs, and the junior scientific posts in AFRC institutes, also provide a valuable source of training and education. New arrangements are introduced when these would be helpful in meeting the immediate and longer-term needs. During 1989/90, the Council launched its "Research Grants to New Investigators" scheme which is designed to support younger research workers in HEIs at an early stage in their careers, and also scientists from outside the usual AFRC disciplines. 20 awards were made during the year. ■

PARTNERSHIPS WITH INDUSTRY

Income to Council and to the Grant-aided institutes from contract research in 1989/90 totalled £62.6M, the major component being MAFF commissions of £46.0M.

The balance, coming from a variety of public and private sector sources, amounted to £16.6M. This exceeded the Corporate Plan target by £0.5M and represents an increase of 10% over the previous year. Industrial support accounts for about 50% of this external funding.

The Council believes firmly that its institutes should attract funding from a variety of sources. Operating in the R & D market helps maintain quality, competitiveness and relevance. Broadening the base of funding also buttresses institutes against fluctuations in public funds. Thus the policy is that 25% of institutes' total income should come from external funding by 1993-94, with each institute aiming at a minimum of 20%. Some institutes have already exceeded this target, others are making good progress. The average in 1989-90 was 20%, compared with 17% in the previous year.

WORKING WITH INDUSTRY

We have continued to build upon our links with industrial companies, both on a one-to-one basis, and through consortia such as those that bring together industrial sponsors and academic partners within the Government's LINK scheme. AFRC currently works with about 200 commercial companies. AFRC income from industry has doubled within the last five years. Examples of collaborative research with industry, often at early pre-competitive stages, appear throughout this Report.

Commercial managers are being appointed at AFRC institutes. They work in concert with the Commercial Policy Unit of Central Office to ensure that AFRC takes full advantage of all marketing opportunities for its research expertise and facilities, and to help effect the technology transfer that is necessary if UK companies are to remain competitive and at the forefront of emerging technologies. Industrialists and other representatives from the private sector play an important and valued role, not only on the Council itself, but also on the Governing bodies and Advisory Boards of AFRC institutes.

EXTERNAL INCOME 1989-90(£'000)

AFRC Institute	Industry	Levy	EC	Government Depts	MAFF Open Contracts	Trusts, Foundations etc.	Sub Total	MAFF Commissions	Total
IAH	630	0	280	437	40	242	1629	6774	8403
IAPGR	652	77	102	674	95	226	1826	2819	4645
IACR	738	1257	275	1130	344	90	3834	5561	9395
IER	670	28	218	883	103	7	1909	4164	6073
IFR	631	0	256	549	417	111	1964	7988	9952
IGER	601	350	100	368	507	0	1926	8540	10466
IHR*	628	499	74	353	33	0	1587	9717	11304
IPSR	1394	54	147	77	1	281	1954	416	2370
TOTAL	5944	2265	1452	4471	1540	957	16629	45979	62608

** Responsibility for horticultural research transferred to the British Society for Horticultural Research with effect from 1 April 1990.*

Major industrial contractors during 1989-90 included :

Agricultural Genetics Company Ltd

Animal Biotechnology Cambridge Ltd

BP International Ltd

British Technology Group

Ciba-Geigy Agrochemicals

Eli Lilly

Germinal Holdings

ICI plc

Intervet plc

Monsanto plc

Pitman-Moore

Rhone Poulenc Agrochemie

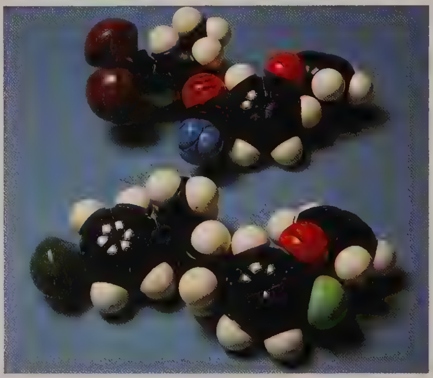
Semundo Ltd

Shell Research Ltd

The special relationship with AGC continues to be of considerable value to AFRC, with contracts of over £1.5M being placed with the three institutes covered by the AFRC/AGC Research and Marketing Agreement.

British Technology Group (BTG) remains an important route for industrial exploitation of AFRC research as well as a major customer for contract research (15 contracts amounting to over £0.5M per annum).

In a major new agreement, BTG is supporting work at the AFRC Institute of Arable Crops Research at Rothamsted on research into improving pesticide "performance" and the development of products that will control pests but have a minimal effect on the environment. The rolling contract is worth £634,000 over the initial three years. It will include investigation of new pyrethrin analogues including some active against soil-inhabiting pests, and "knock down" pyrethroids which allow certain insect species to be controlled without harming the insect predators. Research into new analogues of insect neuropeptides will also be undertaken to identify safer and more specific insecticides. Further research will be undertaken into the development of fungicides and other pesticides that are translocated in the phloem channels of plants, and which when sprayed onto leaves migrate into new plant growth and to the roots to control soil borne pathogens and other pests.



Research supported by BTG led to the discovery of the more photostable pyrethroids, for example deltamethrin (top) which is now an established insecticide with extensive world–wide sales. Subsequent developments include simpler compounds such as "NRDC 199" (bottom), a non–ester pyrethroid with potential for control of some insecticide–resistant insects.

Research "clubs" offer companies a cost effective method of keeping abreast of new developments and participating in research programmes directly relevant to their needs. Examples of this approach include sensor technology projects at the AFRC Institute of Food Research. In one project on moisture sensing, a total of eight food manufacturing companies and an instrumentation company are working together with the institute researchers.

Major fertiliser manufacturers (through the Fertiliser Manufacturers' Association) together with ADAS and DAFS fund the design and analysis of the annual survey of fertiliser practice, carried out by the AFRC Institute of Arable Crops Research. Annual reports and computer summaries are provided to the survey sponsors. At a time when farming practices are changing fairly rapidly, the survey is a unique means of monitoring fertiliser use in British agriculture. Results help manufacturers to estimate future requirements in production and distribution.

In collaboration with ADAS, chemical engineers and computer scientists at the AFRC Institute of Engineering Research have devised WEES - a Waste Engineering Expert System that can help farmers solve disposal problems. At present, the WEES program is confined to problems of air and water pollution from pig slurry, but when complete, it will offer farmers (probably through the regional farm adviser) up-to-date advice on all waste disposal methods, tailored to their own particular problems.

LINK

The Government's LINK scheme is a major initiative in collaboration with industry. AFRC is fully involved as a co-sponsor of six programmes:

Control of Plant Metabolism

Protein Engineering

Eukaryotic Genetic Engineering

Molecular Sensors

Design of High Speed Machinery

Industrial Use of Crops

AFRC institutes act as science-base partners in these and other programmes. For example, a three year project costing £840,000 is to be conducted at the AFRC Institutes of Plant Science Research on plants as part of the Eukaryotic Genetic Engineering programme. The project, which is on plant gene expression, will concentrate on long range gene mapping and cereal transformation. The industrial sponsors are Ciba-Geigy, Advanced Technologies Cambridge, Plant Breeding International and AGC. Government funding is shared equally between AFRC and DTI. ■

INDUSTRIAL USE OF AGRICULTURAL CROPS

AFRC is leading a new £6M LINK programme on collaborative research on the industrial use of agricultural crops in the UK. The co-sponsors are MAFF, DAFS, SERC, DTI and industry. The aims of the programme include the reduction of pollution from crop residues, the alternative use of land for non-food products which have economic value to the farmer, and the reduction of imports.

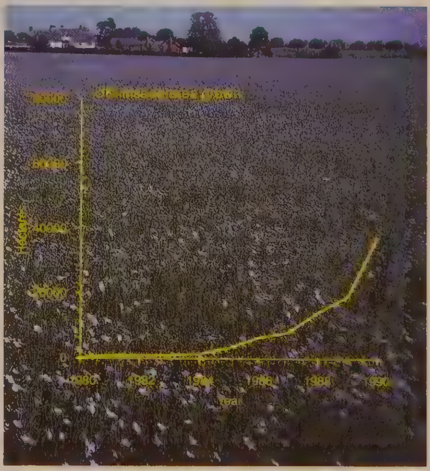
The programme will provide the basic scientific information that could help UK industry exploit resources that are at present under utilised. The agricultural sector will benefit by the development of non-traditional uses for land with a potential for higher returns than are available from traditional crops or alternatives such as "Set Aside".

The programme will deal mainly with annual and short rotation crops, and with non-food industrial uses such as those relevant to the paper and pulp, construction materials, animal feeds and plastics industries.

The programme will include:

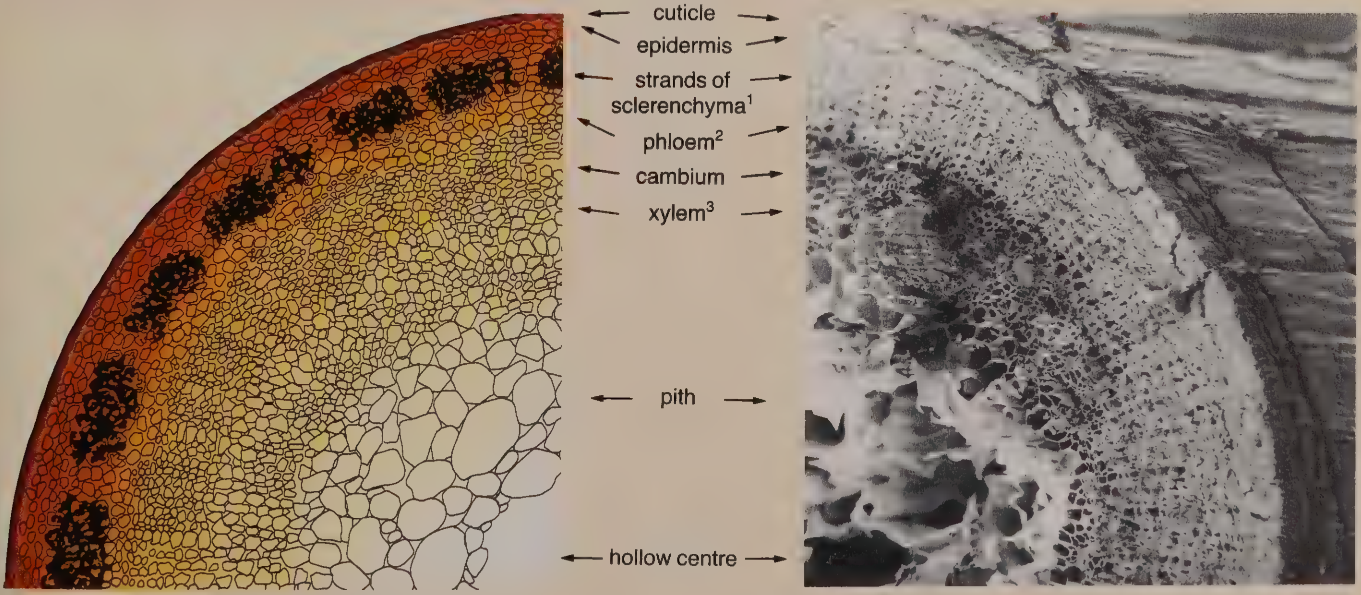
- **properties of plant fibres** (e.g. use of new fibre sources and improving raw materials)
- **crop fractionation** (e.g. separating wheat straw into components suited for different industrial uses)
- **chemical and enzymic treatment of crop components and by-products**
- **manipulation of cereal starch** (e.g. in development of biodegradable plastics)
- **new oils from oil-seed crops** (e.g. genetic manipulation to increase supply of industrially useful fatty acids)

The AFRC Institute of Engineering Research has already started a programme of work on the harvesting and processing of linseed straw which is aimed at determining both agronomic and engineering factors which affect the resultant fibre yield and quality. Since linseed and flax are both cultivars of *Linum usitatissimum* both are capable of producing fibre and oilseed of varying quality and quantity.



The acreage of linseed grown for oil in the UK is increasing significantly. Its potential as a source of industrial grade fibre is being explored.

The acreage of linseed grown for oil in the UK is increasing significantly. At IER a method for extracting industrial grade fibre from linseed is being developed using the stripper harvester to first remove the seeds. The remaining parts of the straw, consisting of woody stem, leaves and chaff, can then be returned to the soil for incorporation or used for boiler fuel or animal feed. ■



Transverse section of Linum usitatissimum *stem.*

1 fibre bundles in cortex
2 soft vascular tissue
3 woody vascular tissue

STAFF

On 31 March 1990, there were 3483 staff employed on permanent appointments and 320 vacancies in the institutes of the Agricultural and Food Research Council. Of these posts, 2007 were in the Science Group, of which 182 were Assistant Scientific Officers. The remainder comprised mainly the Professional and Technology Group, the Administration Group and Industrial Grades. There were a further 590 short-term posts, principally in the Science Group, 220 of which were AFRC-funded and 370 funded by industry, other Government bodies and other organisations. The number of permanent staff in AFRC Central Office, including the Computing Division was 195. The core Central Office complement at Swindon was 153, or 3.6% of the numbers employed in AFRC.

Reductions in MAFF commissioned expenditure for 1990/91, together with increased running costs, resulted in further reductions in manpower during the period covered by this Report. A net 147 permanent posts have been lost in AFRC-funded institutes. However, losses have been off-set by the creation of new posts in areas of higher scientific priority. Redundancies continue to be kept to a minimum. Wherever possible, staff under threat of redundancy are redeployed to new work or to vacancies.

Arrangements under which pay is being linked to performance continues. In certain circumstances, there is also scope to make pay additions locally to combat recruitment or retention problems where particular skills are at a premium or where a location has a bearing on pay. Arrangements exist for special bonus payments for some particular achievements and for terminal bonuses for temporary staff on period appointments.

Delegation of authority in the personnel field, linked to responsibility and accountability, continues wherever this can lead to greater efficiency and effectiveness.

The following changes took place between 1 April 1989 and 31 March 1990.

Deputy Secretary: Professor J P Hearn resigned with effect from 16 February 1990.

CHANGES IN DIRECTORSHIP

AFRC Institute of Animal Physiology and Genetics Research

Professor R B Heap FRS was appointed Director of Animal Physiology and Genetics Research with effect from 10 April 1989, in succession to Dr B A Cross CBE FRS who retired on 7 April 1989. Dr Heap was formerly Head of the Cambridge Research Station.

AFRC Institute of Arable Crops Research

Professor T Lewis, Head of Rothamsted Experimental Station, was appointed Acting Director of Arable Crops Research with effect from 17 July 1989, following the death of Professor K J Treharne.

SENIOR STAFF CHANGES

AFRC Central Office

Dr A V Harrison was appointed Head of Policy, Planning and Assessment Group with effect from 11 September 1989.

Mr S H Visscher was appointed Chief Finance Officer with effect from 19 February 1990. Mr Visscher was previously Secretary of the AFRC Institute of Engineering Research.

AFRC Institute for Animal Health

Dr A I Donaldson was appointed Head of the Pirbright Laboratory with effect from 1 July 1989.

AFRC Institute of Animal Physiology and Genetics Research

Dr R G Dyer was appointed Head of the Cambridge Research Station with effect from 15 May 1989.

Mr P Shaw MBE was appointed Institute Secretary with effect from 1 September 1989, in succession to Mr B E Faulkner, who retired on 30 September 1989.

AFRC Institute of Arable Crops Research

Professor P R Shewry was appointed Head of the Long Ashton Research Station with effect from 1 July 1989.

AFRC Institute of Engineering Research

Mr D Temperley was appointed Institute Secretary with effect from 5 March 1990.

AFRC Institute of Grassland and Environmental Research

Mr P Swinburne was appointed Institute Secretary with effect from 1 November 1989.

FELLOWSHIP OF THE ROYAL SOCIETY

Dr M A Surani, AFRC Institute of Animal Physiology and Genetics Research, was elected a Fellow of the Royal Society.

INDIVIDUAL MERIT PROMOTIONS

Four members of AFRC staff were awarded Individual Merit Promotion in 1989/90 on the recommendation of the Civil Service Individual Merit Panel. There was one such promotion to Grade 4 and three to Grade 6. This brings the total number of AFRC scientific staff who currently hold Individual Merit status to 37: one at Grade 4, three at Grade 5 and 33 at Grade 6.

Those promoted with effect from 1 July 1989 were:

To Grade 4

Professor D A Hopwood FRS, AFRC Institutes of Plant Science Research, John Innes Institute.

To Grade 6

Dr R Eady, AFRC Institutes of Plant Science Research, Nitrogen Fixation Laboratory.

Dr F Sepulveda, AFRC Institute of Animal Physiology and Genetics Research, Cambridge Research Station.

Dr R N F Thorneley, AFRC Institutes of Plant Science Research, Nitrogen Fixation Laboratory.

HONOURS AND AWARDS

Birthday Honours

Knight Bachelor
Dr B A Cross CBE FRS, formerly Director of the AFRC Institute of Animal Physiology and Genetics Research.

MBE
Mr B J Egan, Station Engineer, AFRC Institute for Animal Health, Houghton Laboratory.

BEM
Mr W H Strong, formerly Farm Foreman at the former National Institute for Research in Dairying.

New Year Honours

CBE
Professor J Matthews, Director of AFRC Institute of Engineering Research.

OTHER DISTINCTIONS

Dr M J Berridge FRS, AFRC Laboratory of Molecular Signalling (IAPGR) was awarded the 1989 Albert Lasker Basic Medical Research Award.

Dr J Brownlie, AFRC Institute for Animal Health, was awarded the Royal Agricultural Society of England Research Medal.

Dr M D Collins, AFRC Institute of Food Research, was awarded the Bergey Trust Award.

Dr J Dauncey, AFRC Institute of Animal Physiology and Genetics Research and Dr A Prentice, of the MRC Dunn Nutrition Unit, shared the 1989 Peter Debye Prize.

Dr T Elliott, AFRC Institute of Horticultural Research, was awarded the UK Mushroom Growers Association Sinden Award.

Dr V Jordan, AFRC Institute of Arable Crops Research, was awarded a Certificate of Associateship of the Royal Agricultural Societies.

Dr R A Leigh, AFRC Institute of Arable Crops Research, was awarded one of the 1989 Locker Awards.

Dr L N Payne, AFRC Institute for Animal Health, was awarded the Professor Karla Sobry Memorial Medal.

Dr R M Sawicki FRS, AFRC Institute of Arable Crops Research, was awarded a British Crop Protection Council medal.

Dr M W Shirley, AFRC Institute for Animal Health, was awarded the 1989 Tom Newman Memorial Award.

Professor D Southgate, AFRC Institute of Food Research, was awarded the 1989 British Nutrition Foundation Prize.

Dr C Thomas, Dr M Gill and Mr K Aston, AFRC Institute of Grassland and Environmental Research (together with Dr A Reeve of ICI) were awarded the Roche Livestock Nutrition Award.

Dr R Wilkins, AFRC Institute of Grassland and Environmental Research, was awarded the British Grassland Society Award.

The AFRC Institute of Engineering Research was awarded a special RASE Silver Medal.

DEATHS

Professor H Donald CBE FRSE, former Director of the Animal Breeding Research Organisation of the AFRC Institute of Animal Physiology and Genetics Research, died on 21 August 1989.

Dr L E A Rowson OBE FRS, who was former Deputy Director of the AFRC Unit of Reproductive Physiology and Biochemistry at the AFRC Institute of Animal Physiology and Genetics Research, died on 26 July 1989.

Professor K J Treharne, who was Director of Arable Crops Research, died on 14 July 1989.

Dr J E Treherne, who was Honorary Director of the Institute of Arable Crops Research Unit of Insect Neurophysiology and Pharmacology, died on 23 September 1989.

FINANCIAL REPORTS

For the financial year ending 31 March 1990, the gross expenditure of the Council and Council owned institutes was ***£130,463,000.***

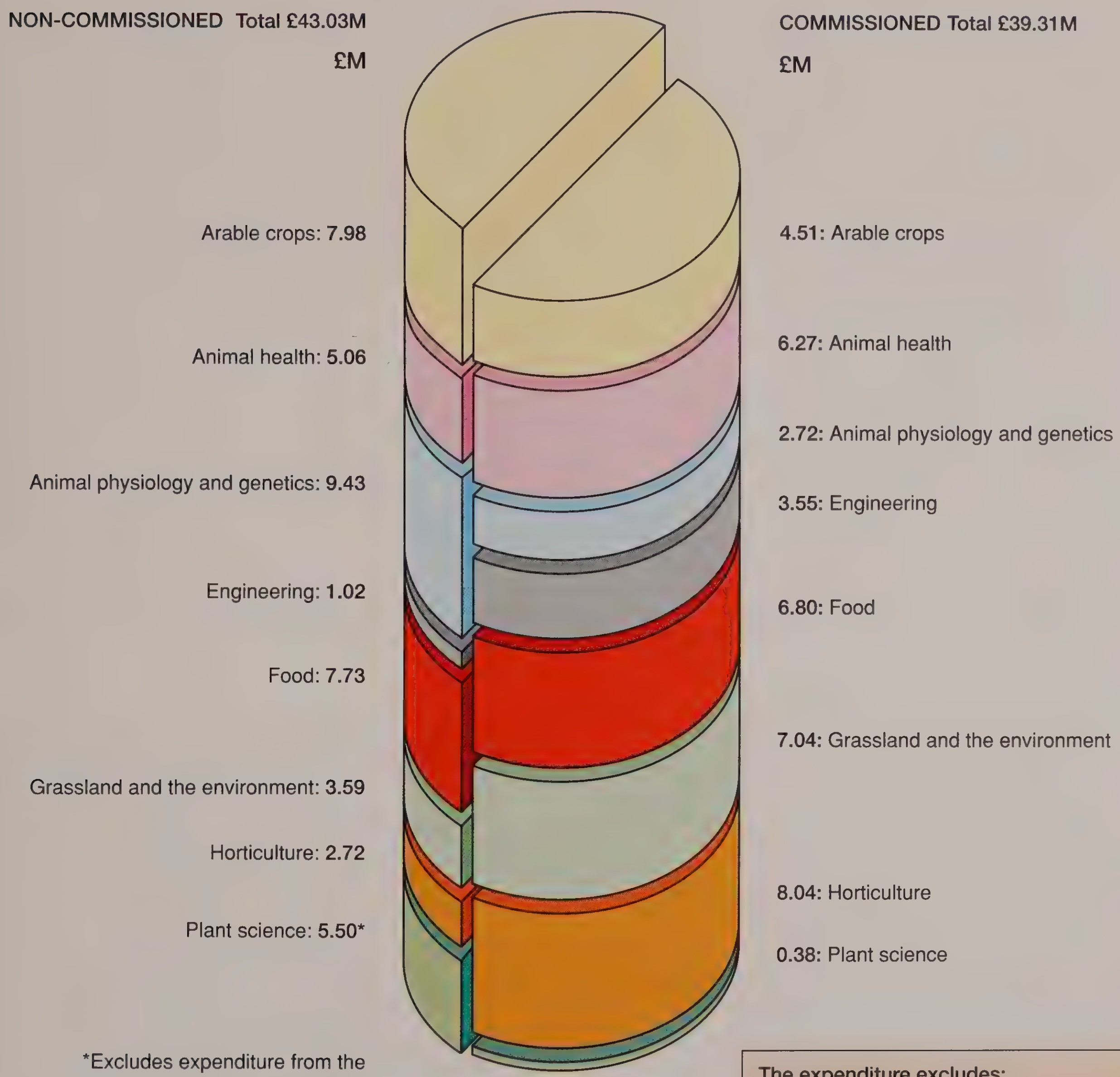
The expenditure was financed from the following sources:

Parliamentary grant-in-aid was ***£74,311,000*** *and a further amount of* ***£45,979,000*** *was received from the Ministry of Agriculture, Fisheries and Food in respect of commissioned research.*

This major funding was augmented by further Council receipts totalling ***£11,096,000*** *being mainly capital receipts, contract and other income from industry and Government organisations. The rest came from miscellaneous sales, mainly of livestock and farm produce, and from superannuation contributions.*

In addition to this income received by the Council, grant-aided institutes received outside funding estimated at ***£12.84M*** *from contracts and other agreements with industry, Government Departments, EC, Foundations and Trusts etc. This income is included in the table on page 61.*

SUMMARY OF NET EXPENDITURE - 1989-90 - BETWEEN ACTIVITY AREAS



*Excludes expenditure from the Institutes of Plant Science Research own funds.

The expenditure excludes:

Research grants	£15.00M
AFRC Central Computing and Administrative costs	£6.44M
Superannuation and Redundancy	£15.26M
Postgraduate Awards	£1.26M
Receipts from Sale of land	£3.64M
Relocation of Central Office	£2.20M

GRANT-IN-AID ACCOUNT

SUMMARY OF EXPENDITURE OF THE COUNCIL FOR THE YEAR ENDED 31 MARCH 1990

		1988/89		1989/90	
		£'000	£'000	£'000	£'000
	RECEIPTS				
	Balance at 1 April		206		**256**
	Parliamentary Grant-in-Aid	61,112		**74,311**	
	Receipts from MAFF	46,381	107,493	**45,979**	**120,290**
	Other receipts				
Note A	Council Institutes and Units	4,532		**5,281**	
	Superannuation contributions	1,385		**1,899**	
	Miscellaneous	442		**274**	
	Sale of Land and Buildings	45	6,404	**3,642**	**11,096**
	TOTAL RECEIPTS (including balance brought forward)		114,103		**131,642**
		£'000	£'000	£'000	£'000
	PAYMENTS				
	Recurrent Expenditure				
	Administrative and Central running costs		6,747		**6,435**
	Superannuation and staff restructuring costs		15,741		**17,161**
Note A	Council Institute and Unit running costs		25,506		**27,716**
Note B	Grant-aided Institutes and other organisations		42,531		**44,301**
	Universities and other bodies:				
	Current	7,471		**9,044**	
	Capital	1,609	9,080	**5,957**	**15,001**
	Postgraduate Training Awards		937		**1,263**
	Capital Expenditure				
	Central Office: Land and Buildings	679		**2,033**	
	Capital Equipment	2,083	2,762	**836**	**2,869**
Note A	Council Institutes: Land and Buildings	1,437		**3,280**	
	Capital Equipment	1,901	3,338	**3,132**	**6,412**
Note B	Grant-aided Institutes: Land and Buildings	3,365		**4,777**	
	Capital Equipment	3,840	7,205	**4,528**	**9,305**
	Balance at 31 March		256		**1,179**
	TOTAL PAYMENTS (including balance carried forward)		114,103		**131,642**

Note A. Breakdown of the net expenditure of the research establishments of the Council

AFRC Institutes	Current Expenditure £'000	Capital Expenditure £'000	Receipts £'000	Net Total £'000
Institute of Animal Physiology and Genetics Research	12,003	2,957	2,808	12,152
Institute of Food Research	13,810	3,123	2,406	14,527
Institute of Arable Crops Research (Unit of Insect Neurophysiology and Pharmacology)	498	43	–	541
Institutes of Plant Science Research (Nitrogen Fixation Laboratory)	1,405	289	67	1,627
TOTAL	**27,716**	**6,412**	**5,281***	**28,847**

*Sale of produce etc.	£1,594,000
Rent and hostel receipts	£251,000
External contracts	£3,436,000
Total	**5,281,000**

Note B. Grants to grant-aided Institutes and others

Establishments	Current Expenditure £'000	Capital Expenditure £'000	Net Total £'000
Institute of Arable Crops Research	10,151	1,794	11,945
Institute for Animal Health	8,257	3,076	11,333
Institute of Engineering Research	4,057	510	4,567
Institute of Grassland and Environmental Research	8,772	1,903	10,675
Institute of Horticultural Research	9,679	1,080	10,759
Institutes of Plant Science Research	3,242	942	4,184
London Zoo/MRC Unit	120	–	120
Others	23	–	23
TOTAL	**44,301**	**9,305**	**53,606**

RESEARCH COMMITTEES

ANIMALS RESEARCH COMMITTEE at 31 March 1990

Chairman

Mr Maitland Mackie
Mackie's Aberdeen Dairy Co Ltd

Members

Dr I D Aitken MRCVS
Director, Moredun Research Institute

Professor D G Armstrong FRSE
Department of Agricultural
Biochemistry and Nutrition
University of Newcastle-upon-Tyne

Professor R B Beechey FRSC
Department of Biochemistry and
Agricultural Biochemistry
University College of Wales
Aberystwyth

Professor F J Bourne MRCVS
Director of Animal Health Research

Professor A W Cuthbert FRS
Department of Pharmacology
University of Cambridge

Professor R B Heap FRS
Director of Animal Physiology and
Genetics Research

Professor W P T James FRCP FRCP(E)
Director, Rowett Research Institute

Professor W F H Jarrett FRS
Department of Veterinary Pathology
University of Glasgow

Professor J R Krebs FRS
Department of Zoology
University of Oxford

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AFRC Science Division

Professor G E Lamming OBE
Faculty of Agricultural Sciences
University of Nottingham

Dr J M Randall
AFRC Institute of Engineering
Research

Professor R J Roberts FRSE
Institute of Aquaculture
University of Stirling

Dr D W F Shannon
Chief Scientist, Agriculture and
Horticulture, MAFF

Professor J L Stoddart
Director of Grassland and
Environmental Research

Mr D Thornton
DAFS

Mr S Vranch
Celltech Ltd

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Department of Biological Sciences
University of Warwick

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Professor E D T Atkins
H H Wills Physics Laboratory
University of Bristol

Professor T L Blundell FRS
Department of Crystallography
Birkbeck College

Dr S Dyer
Medical Research Council

Dr D B Gammack
Consultant

Professor D L Georgala CBE
Director of Food Research

Dr T T Gorsuch
Consultant

Dr M E Knowles
Chief Scientist, Fisheries and Food,
MAFF

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AFRC Science Division

Dr B J Legg
AFRC Institute of Engineering
Research

Professor P J Lillford
Unilever Research

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School of Chemical Engineering
University of Birmingham

Professor J R Norris
Director of Group Research
Cadbury Schweppes plc

Professor M Peaker
Director, Hannah Research Institute

Professor C Ratledge
Department of Applied Biology
University of Hull

Mr D Thornton
DAFS

PLANTS AND ENVIRONMENT RESEARCH COMMITTEE at 31 March 1990

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Emeritus Professor of Botany
University College of North Wales

Members

J C Beynon
Welsh farmer

Professor D Boulter
Department of Biological Sciences
University of Durham

Dr J T Braunholtz
Horticultural Development Council

Professor E C D Cocking FRS
Department of Botany
University of Nottingham

Professor P T Haskell CMG
University of Wales, College of Cardiff

Dr T W Hegarty
DAFS

Professor J R Hillman
Director, Scottish Crop Research
Institute

Dr J V Lake
AFRC Science Division

Professor T Lewis
Acting Director of Arable Crops
Research

Professor T A Mansfield FRS
Department of Biological Sciences
University of Lancaster

Professor J Matthews CBE
Director of Engineering Research

Professor J A Raven FRS
Department of Biological Sciences
University of Dundee

Professor J L Stoddart
Director of Grassland and
Environmental Research

Professor T R Swinburne
Director of Horticultural Research

Professor J K Syers
Department of Agricultural and
Environmental Science
University of Newcastle-upon-Tyne

Professor M H Unsworth
Department of Physiology and
Environmental Science
University of Nottingham

Dr D J White
Assistant Chief Scientist, Agriculture
and Horticulture, MAFF

Professor H W Woolhouse
Director of Plant Science Research

ENGINEERING ADVISORY GROUP at 31 March 1990

Chairman

Professor A W Nienow FEng
School of Chemical Engineering
University of Birmingham

Members

Professor B G Batchelor
Department of Physics, Electronic and
Electrical Engineering
University of Wales, College of Cardiff

Dr R J Dowdell
DAFS

Professor J Matthews CBE
Director of Engineering Research

Professor J R O'Callaghan
Department of Agricultural and
Environmental Science
University of Newcastle-upon-Tyne

Mr E C Pape
RHM Research and Engineering
Limited

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Department of Food Science and
Technology
University of Reading

Mr S Vranch
Celltech Ltd

Dr D J White
Assistant Chief Scientist, Agriculture
and Horticulture, MAFF

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Chief Executive
Wolseley, Agriculture Division
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RESEARCH GRANTS BOARDS

ANIMALS RESEARCH GRANTS BOARD at 31 March 1990

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Department of Veterinary Pathology
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University of Nottingham

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University of Nottingham

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Kings College
University of London

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Department of Agricultural Biochemistry and Nutrition
University of Newcastle-upon-Tyne

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Institute of Animal Genetics
University of Edinburgh

Dr D F Houlihan
Department of Zoology
University of Aberdeen

Professor I McConnell FRSE
Department of Veterinary Pathology
University of Edinburgh

Professor D Onions
Department of Veterinary Pathology
University of Glasgow

Professor B T Pickering
Department of Anatomy
University of Bristol

Dr E Simpson
Clinical Research Centre
Northwick Park Hospital

Dr D C Wathes
Department of Anatomy
University of Bristol

Professor A J F Webster
Department of Animal Husbandry
University of Bristol

FOOD RESEARCH GRANTS BOARD at 31 March 1990

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Department of Applied Biology
University of Hull

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Division of Biotechnology
Polytechnic of Central London

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MRC Dunn Nutrition Unit, Cambridge

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Department of Physics
University of Cambridge

Dr P J Frazier
Dalgety plc

Professor A Godfrey
Biocatalysts Ltd

Professor C F Higgins
Imperial Cancer Research Fund Laboratories
University of Oxford, Institute of Molecular Medicine

Dr J Mann
Consultant
Loughborough

Professor A W Nienow FEng
School of Chemical Engineering
University of Birmingham

Professor D S Robinson
Procter Department of Food Science
University of Leeds

Dr D M H Thomson
Consultant
Oxfordshire

Dr P D Walker
Wellcome Biotech

PLANTS AND ENVIRONMENT RESEARCH GRANTS BOARD
at 31 March 1990

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Department of Biology
University College London

Members

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School of Biological Sciences
University of Birmingham

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Department of Botany
University of Nottingham

Professor H G Dickinson
Department of Botany
University of Reading

Professor D Grierson
Department of Physiology and
Environmental Science
University of Nottingham

Dr P S Grubb
Department of Botany
University of Cambridge

Professor M P Hassell FRS
Department of Pure and Applied
Biology
Imperial College

Dr C N Hunter
Department of Molecular Biology and
Biotechnology
University of Sheffield

Dr D S Ingram
Royal Botanic Gardens
Edinburgh

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University of Oxford

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Biology
University of Leeds

Professor R Leech
Department of Biology
University of York

Professor S P Long
Department of Biology
University of Essex

Professor J R O'Callaghan
Department of Agricultural and
Environmental Science
University of Newcastle-upon-Tyne

Professor J K Syers
Department of Agricultural and
Environmental Science
University of Newcastle-upon-Tyne

Professor M H Unsworth
Department of Physiology and
Environmental Science
University of Nottingham

Dr A Vivian
Department of Science
Bristol Polytechnic

Professor A E Walsby
Department of Botany
University of Bristol

AFRC INSTITUTES

AFRC INSTITUTE FOR ANIMAL HEALTH (IAH)

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Near Newbury
Berkshire RG16 0NN
Tel: (0635) 578411
Fax: (0635) 578844
Director: Professor F J Bourne

AFRC INSTITUTE OF ANIMAL PHYSIOLOGY AND GENETICS RESEARCH (IAPGR)

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IACR AFRC Institute of Arable Crops Research

IAH AFRC Institute for Animal Health

IAPGR AFRC Institute of Animal Physiology and Genetics Research

IER AFRC Institute of Engineering Research

IFR AFRC Institute of Food Research

IGER AFRC Institute of Grassland and Environmental Research

IHR AFRC Institute of Horticultural Research

IPSR AFRC Institutes of Plant Science Research

OTHER ACRONYMS

ABRC Advisory Board for the Research Councils

ADAS Agricultural Development and Advisory Service

AFRC Agricultural and Food Research Council

AFRS Agricultural and Food Research Service

AGC Agricultural Genetics Company

BAP Biotechnology Action Programme

BRIDGE Biotechnology Research for Innovation Development and Growth in Europe

BTG British Technology Group

CEC Commission of the European Communities

CEMAGREF Centre National du Machinisme Agricole du Génie Rural des Eaux et des Forêts

DAFS Department of Agriculture and Fisheries for Scotland

DES Department of Education and Science

DNA Deoxyribose nucleic acid

DTI Department of Trade and Industry

EC European Community

ECLAIR European Collaborative Linkage of Agriculture and Industry through Research

EEC European Economic Community

EFTA European Free Trade Association

ESRC Economic and Social Research Council

FAO Food and Agriculture Organisation

FLAIR Food Linked Agro-Industrial Research

FMD Foot-and-Mouth Disease

FMDV Foot-and-Mouth Disease Virus

HEI Higher Education Institution

IBPGR International Board for Plant Genetic Resources

ICRF Imperial Cancer Research Fund

ICRISAT International Crops Research Institute for the Semi-Arid Tropics

IITA International Institute of Tropical Agriculture

INRA Institut National de la Recherche Agronomique

JII John Innes Institute

MAFF Ministry of Agriculture, Fisheries and Food

MCF Malignant Catarrhal Fever

MLURI Macaulay Land Use Research Institute

MRC Medical Research Council

MRI Moredun Research Institute

NERC Natural Environment Research Council

NFL Nitrogen Fixation Laboratory

ODA Overseas Development Administration

ODNRI Overseas Development Natural Resources Institute

OIE Office International des Epizooties

PDGF Platelet derived growth factor

RFLP Restriction Fragment Length Polymorphism

RNA Ribose nucleic acid

RRI Rowett Research Institute

SARI Scottish Agricultural Research Institute

SCRI Scottish Crop Research Institute

SERC Science and Engineering Research Council

SSSI Site of Special Scientific Interest

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